DOCUMENT RESUME

ED 341 622 SO 021 875

TITLE	How Federal Spending for Infrastructure and Other Public Investments Affects the Economy.
INSTITUTION	Congress of the U.S., Washington, D.C. Congressional Budget Office.
PUB DATE	Jul 91
NOTE	118p.
PUB TYPE	Reports - Evaluative/Feasibility (142)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Economic Factors; Economic Impact; Economic Research; *Economics; *Federal Government; Federal Programs; *Government Role; *Investment; Public Policy; *Public Sector

ABSTRACT

Despite pressures for reducing the overall spending of the federal government, some policymakers and analysts have considered increasing the funding for particular areas that might be especially important to the long-term growth of the economy. Increases have been proposed in spending for highways and other types of physical infrastructure, for education, and for research and development. At the request of the Rules Committee of the House of Representatives, the Congressional Budget Office (CBO) has prepared this study of the economic effects of federal investment spending. In particular, this study examines the effect on the economy of three broad classes of federal investment spending: physical infrastructure, including programs for transportation and environmental facilities; human capital, including programs that increase the skills and productive knowledge that people bring to their jobs; and intangible capital, such as research and development. Within each of these categories, the study examines trends in spending, discusses the rationales for that spending, and reviews evidence on the contribution of public investment to economic performance. The section on "Federal Investment in Human Capital" (p.48-58) covers federal outlays for education. In keeping with CBO's mandate, the study contains no recommendations. A number of tables and figures conveying data are included. (DB)

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CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

JULY 1991

How Federal Spending for Infrastructure and Other Public Investments Affects the Economy

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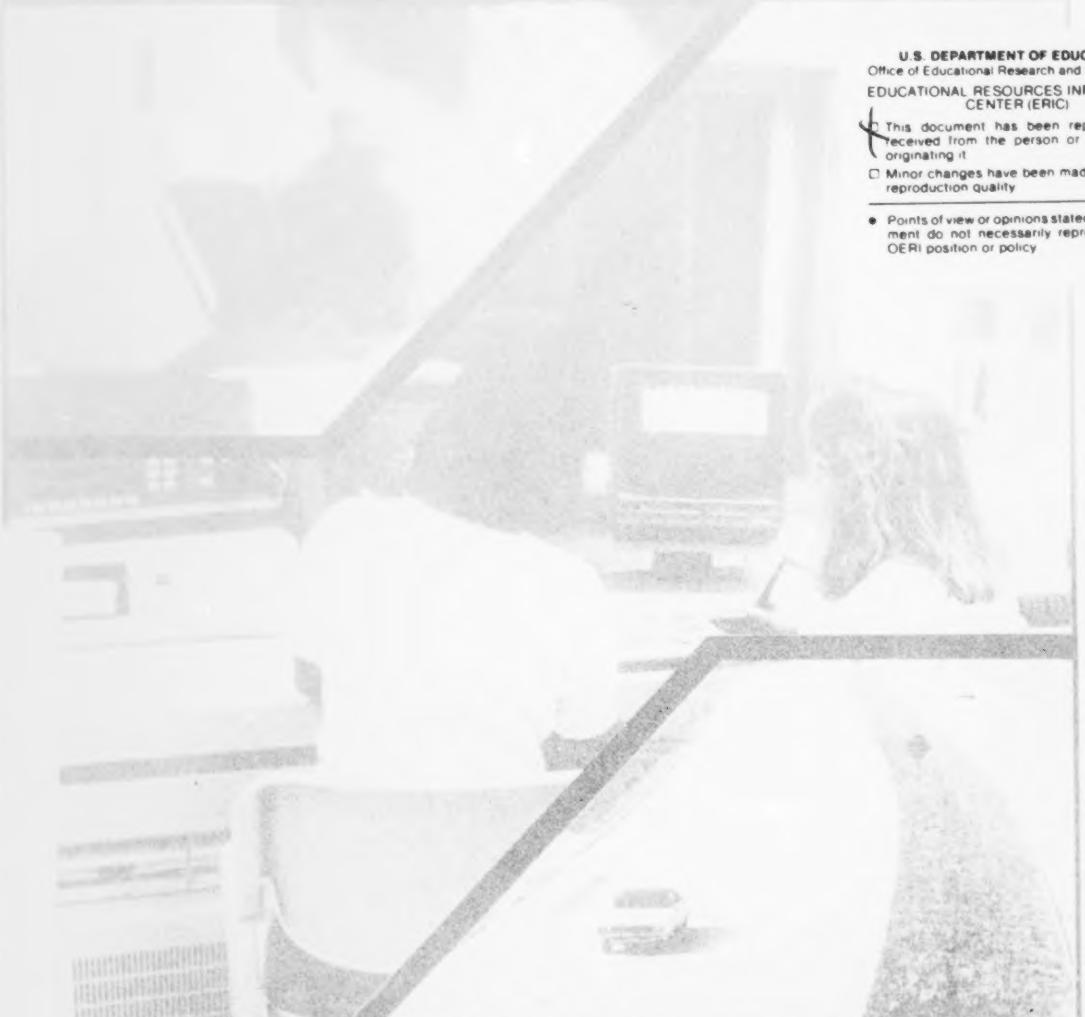

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A CBO STUDY

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HOW FEDERAL SPENDING FOR INFRASTRUCTURE AND OTHER PUBLIC INVESTMENTS AFFECTS THE ECONOMY

The Congress of the United States
Congressional Budget Office

NOTES

Unless otherwise indicated, all years referred to in the text are fiscal years.

Details in the text and tables of this report may not add to totals because of rounding.

PREFACE

Despite pressures for reducing overall federal spending, policymakers and analysts have recently been considering increasing the funding for particular areas that might be especially important to the long-term growth of the economy. Increases have been proposed in spending for highways and other types of physical infrastructure, for education, and for research and development. All can be considered programs of federal investment. If they are chosen carefully, such federal outlays create assets that contribute to the productivity of the economy in future years.

At the request of the House Rules Committee, the Congressional Budget Office (CBO) has prepared this study of the economic effects of federal investment spending. The study describes existing federal programs in several areas and examines the evidence regarding how productive additional federal expenditures might be. In keeping with CBO's mandate, the study contains no recommendations.

Members of CBO's Natural Resources and Commerce, Human Resources and Community Development, and Fiscal Analysis Divisions prepared the study under the general direction of David Montgomery, Frederick Ribe, and Elliot Schwartz. Michael Deich wrote Chapters I and II with the help of Perry Beider. Ralph Smith wrote Chapter III, and David Moore, John Sturrock, and Philip Webre collaborated in the writing of Chapter IV. The authors would like to thank Daryl Chubin, Joseph Cordes, Jon Hakken, Robert Hartman, Charles Hulten, George Iden, David Levy, Jay Noell, Elizabeth Pinkston, Ray Uhalde, and Clifford Winston for valuable comments. Daniel Covitz and Nicholas Dugan provided research assistance.

Sherry Snyder edited the report. Nancy H. Brooks provided editorial support during the production process. Verlinda Lewis and Dorothy Kornegay produced the typescript, and Kathryn Quattrone prepared the report for publication with the assistance of Martina Wojak.

Robert D. Reischauer
Director

July 1991

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SUMMARY

Some analysts and policymakers have voiced concern in recent years that the nation needs to invest more in its transportation facilities, in the "human capital" that is embodied in its citizens, and in the research and development that may lead to tomorrow's economic advances. Partly in response to such concerns, the Administration's budget request for 1992 includes initiatives to expand spending in each of these areas. If they are planned carefully, these expenditures by the federal government can be expected to contribute to the expansion of the economy, or to other aspects of national welfare, for a number of years.

This study examines the effect on the economy of three broad classes of federal investment spending: physical infrastructure, including programs for transportation and environmental facilities; human capital, including programs that increase the skills and productive knowledge that people bring to their jobs; and intangible capital, such as research and development. Within each of these categories, the study examines trends in spending, discusses the rationales for that spending, and reviews evidence on the contribution of public investment to economic performance.

TRENDS IN FEDERAL INVESTMENT

Investment, or capital spending, may be defined broadly as the expenditure of current resources to produce income or other benefits over some period in the future. Investment is distinguished from outlays for consumption, which are intended to provide immediate benefits. The federal budget and most other accounting systems treat all government outlays, even purchases of long-lived assets, as consumption because the purchases cannot clearly be shown to produce income as officially measured. Yet some federal expenditures clearly seem to be investments: like private investments, they produce a stream of economic benefits over time. The conventional definition of investment thus might reasonably be extended to include federal spending for physical infrastructure, some human resource programs, and research and development.

Federal Investment in Physical Infrastructure

The production and distribution of private economic output depends on public transportation and environmental facilities including highways, mass transit, railways, airports and airways, water resources, and water supply and wastewater treatment plants. These public facilities form a significant fraction of the economy's total stock of capital. In 1987, nonmilitary public infrastructure capital was valued at $1.2 trillion compared with private nonresidential capital equal to $4.1 trillion.

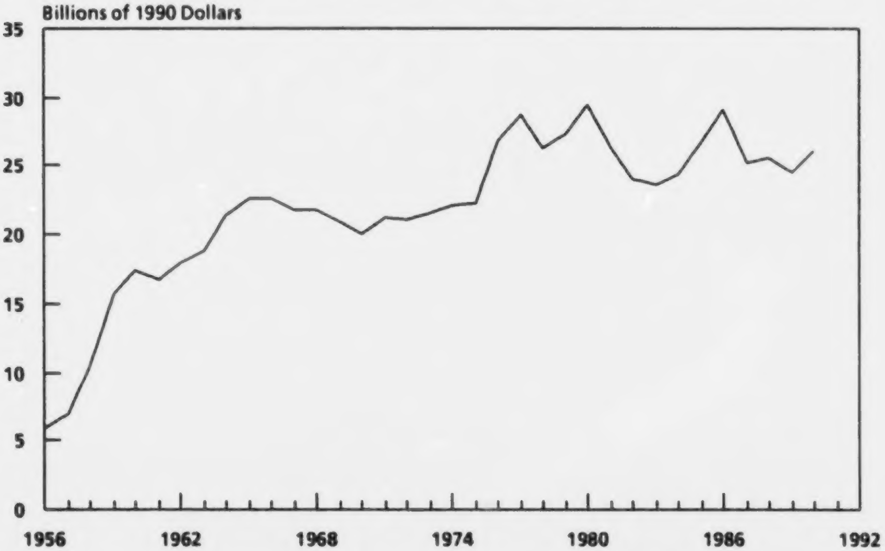
Adjusted for inflation, federal outlays for physical infrastructure rose rapidly between 1956 and 1965, rose again between 1970 and 1980, and have fluctuated around a slight downward trend since then (see Summary Figure 1). Between 1956 and 1970, and again during the 1980s, changes in federal highway outlays accounted for most of the changes in total federal infrastructure investments. During the 1970s, the growth in these investments was driven largely by support for mass transit and for the construction of municipal wastewater treatment plants. In 1990, federal infrastructure investments totaled $26.2 billion, with nearly $14 billion of this amount spent on highways. Under the President's current budget proposal, inflation-adjusted annual infrastructure spending would remain roughly constant through 1992.

Federal Investments in Human Capital

Economic growth depends in part on the skills that people bring to their jobs. Federal programs may contribute to this human capital through programs that offer education, job training, and the informal acquisition of skills through work experience. The broad outlines of federal spending on human capital are found in the portion of the budget covering outlays for education, training, employment, and social services (budget function 500). Outlays for this function rose from about $3 billion in 1960 to $24 billion by 1968, and peaked at $52 billion in 1979. Spending since then has fallen to $38 billion in 1990 (see Summary Figure 2). (These figures and all subsequent figures in this summary are in 1990 dollars.)

Although the spending shown in Summary Figure 2 no doubt shows the broad trend in federal spending for human capital, the exact path of outlays depends on how human capital is defined. In principle, investments in human capital might include all federal outlays that contribute to workers' skill and productivity. In practice, it is difficult to establish the effect of particular federal programs on workers' skills. The notion of investment in human capital therefore remains elastic, and the exact definition is somewhat arbitrary. This report considers three separate definitions of federal outlays for human capital. Under the narrowest criterion, federal spending for human capital in 1990 totaled $26 billion, including about $11 billion for postsecondary

Summary Figure 1.
Federal Capital Spending for Physical Infrastructure, 1956-1990



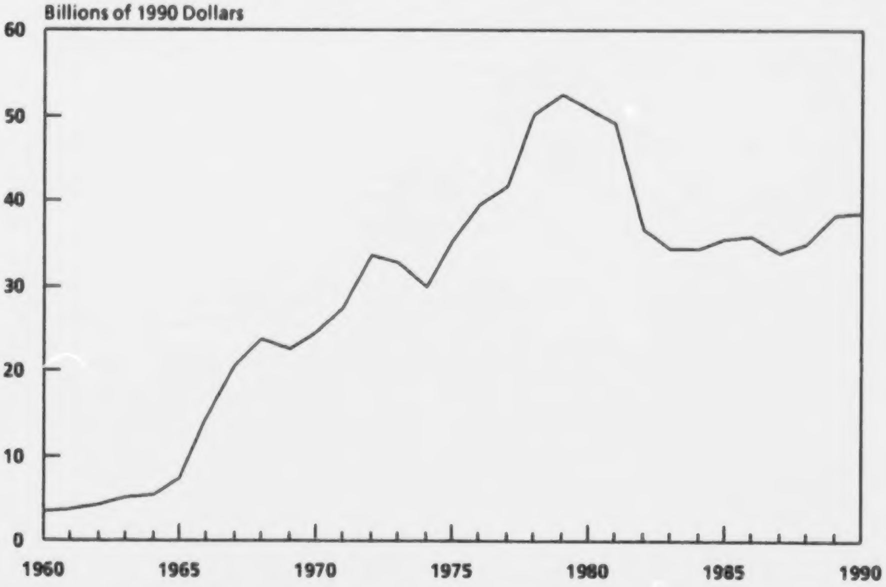
SOURCE: Congressional Budget Office using data from the Office of Management and Budget.

education, $9 billion for elementary, secondary, and vocational education, and $6 billion for job training. Under the broadest criterion, federal outlays totaled $42 billion, including the $26 billion for education and job training, $9 billion for various social services, and $7 billion for certain food and nutrition programs. Adjusting for inflation, the President's budget proposal calls for narrowly defined human capital outlays of about $29 billion in 1992, and more broadly defined human capital outlays of roughly $48 billion in 1992.

Federal Investments in Research and Development

Research and development (R&D) creates a store of knowledge that can be used over time to produce new products or production processes.

Summary Figure 2.
Federal Outlays for Education, Training, Employment, and Social Services, 1960-1990



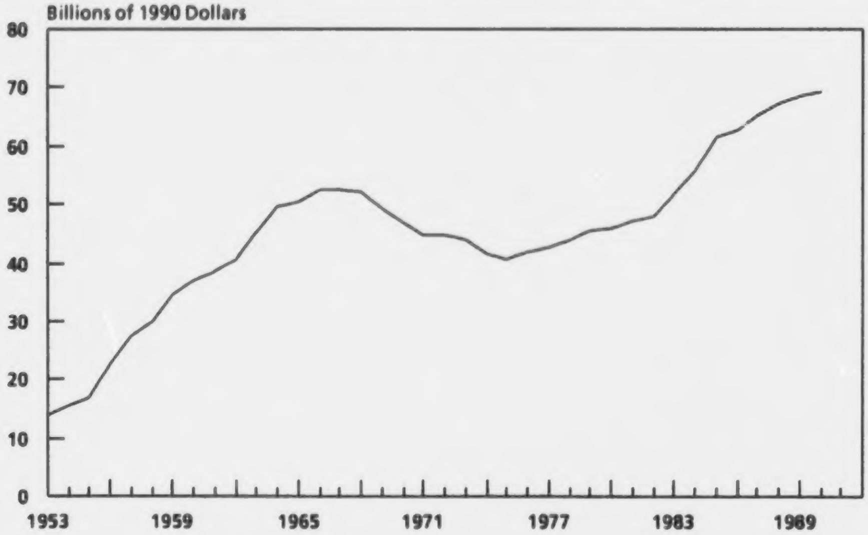
SOURCE: Congressional Budget Office using data from the Office of Management and Budget.

In 1990, federal spending for R&D totaled $67 billion--about 46 percent of all R&D performed in the U.S. economy. Private companies, many with the support of various federal tax preferences for private R&D expenses, accounted for about 49 percent. The remaining 5 percent was spent by universities and nonprofit institutions.

Over 60 percent of federal outlays for R&D support defense-related activities. Most defense work is devoted to developing new weapons, and about two-thirds of total federal R&D outlays also support development work, which involves the incorporation of new knowledge into products and processes. The remaining federal outlays are split about equally between applied research, which seeks to advance knowledge needed to develop new products and processes, and basic research, which seeks to advance knowledge without regard to specific applications.

Adjusted for inflation, federal spending for research and development has had an uneven history (see Summary Figure 3). After quad-

Summary Figure 3.
Federal Support for Research and Development, 1953-1990



SOURCE: Congressional Budget Office; National Science Foundation, *National Patterns of R&D Resources: 1990*, Final Report by J.E. Jankowski, NSF 90-316 (Washington, D.C., 1990).

rupling between 1953 and 1967, federal R&D spending then fell for the next eight years. Since 1976, R&D spending has grown at an annual rate of 3.6 percent. Much of the fluctuation in spending is explained by changes in outlays for defense-related R&D, which were especially strong during the 1960s and 1980s. Federal R&D spending in nondefense areas has grown relatively steadily over the past 10 years, although the distribution of these outlays for health, space, and energy has fluctuated over time. The President's proposal calls for increases throughout the R&D budget. By 1992, federal spending for R&D would rise to $69 billion, of which $41 billion would be for defense.

RATIONALES FOR FEDERAL CAPITAL SPENDING

The rationales for federal investment programs are both economic and social. The economic argument for many programs begins by noting the existence of "market failures," in which private markets fail to provide households, businesses, and state and local governments with the incentives needed to produce enough capital spending to maximize gross national product. Market failure occurs most commonly because some expenditures yield benefits that go beyond the responsibility of individual companies or of subnational levels of government. Local governments, for example, may not spend enough on highways because some of the benefits go to taxpayers of other jurisdictions, who are not represented in local decisionmaking. It then falls to the federal government to ensure that enough investment is made to satisfy national preferences.

Market failures and other narrowly economic arguments provide one rationale for federal investment. A second significant rationale is based on social goals, rather than economic considerations. Many federal programs, for example, have been designed to standardize the level of some goods and services for all parts of the country and all segments of society.

HOW MUCH PUBLIC INVESTMENT IS ENOUGH?

In most circumstances, federal investment spending can be increased only by diverting resources from other uses--either from investment by the private sector or from consumption by the public or private sector. Thus, greater federal investment will increase aggregate welfare only as long as the extra dollar invested yields benefits that are greater than those derived from alternative uses of the funds. The added capital spending, in other words, must yield not only a positive return, but a return greater than that which could be achieved by using the funds for some other purpose.

The evidence surveyed in this report leads to some useful generalizations about the returns to federal investment spending. Yet this evidence should be viewed with some caution because the studies from which it comes suffer various technical limitations, and because not enough studies have been done to represent the full range of potential returns to federal investment.

Physical Infrastructure

Carefully chosen federal investments in physical infrastructure such as highway and aviation projects would yield economic rates of return higher than the average return on private capital. As a rule, the highest economic benefits would result from maintaining existing infrastructure assets and from expanding capacity in highly congested facilities. Substantial economic benefits also can be achieved by using existing assets more efficiently. In many cases, price mechanisms can significantly increase the efficiency with which infrastructure is used.

Some recent studies, however, have exaggerated the importance of additional physical infrastructure. These studies have suggested that every dollar spent on projects such as roads, sewers, and airports offers a significantly higher rate of return than would the same amount of private-sector investment in assets such as business plants and equipment. The evidence reviewed in this study, however, shows that there is little basis for this conclusion. Although further, carefully selected investments in public infrastructure may well be productive, there is little evidence to suggest that substantial, across-the-board increases in current programs would be more productive on average than private investment.

Human Capital

The economic effects of some federal human resource programs, particularly job training programs, have been measured in terms of their impact on the participants' earnings. Overall, training programs appear to have led to modest gains in the average earnings of program participants.

Most human resource programs, however, were designed principally to further noneconomic goals, and these programs generally have not been assessed for their economic returns. Evaluations of most social service and food and nutrition assistance programs, in particular, have focused on results less directly related to economic growth. For example, evaluations of a supplemental food program found that it increased the average birthweight of infants born to participating mothers. Measuring the effect of these programs on gross national product, however, remains difficult.

Research and Development

Limited evidence suggests that federal funding of certain types of research and in certain areas offers significant economic benefits. Economic measures suggest generally high rates of return for basic research and academic research in science and engineering, for example, which accounts for about 25 percent of all federally funded R&D. Research in health and agriculture also appear to yield significant economic benefits.

Most other federally funded R&D, however, appears to expand productivity significantly less effectively than privately funded R&D. To some extent, this lack of positive evidence may reflect measurement problems that obscure the contribution of federally funded R&D. In addition, most federally funded R&D supports the goals of various federal agencies, such as defense or space exploration. But in most cases, the goals of the agencies cannot be measured in economic terms. As a result, spending for such R&D is best evaluated on the basis of its contribution to the goals of the funding agency, rather than on claims of ancillary economic benefits.

CHAPTER I

INTRODUCTION

The Administration's 1992 budget proposal includes a number of initiatives to expand federal investments in such areas as roads, airports, education, and other assets that can be expected to make long-term contributions to the nation's income and welfare. The proposed budget reflects concerns voiced by a number of analysts that both economic growth and the nation's quality of life require greater federal spending on such public investments. Yet the Budget Enforcement Act of 1990 requires that for the next few years any increase in spending in those areas be offset by reductions in other discretionary domestic programs. The Congress thus must decide not only how to allocate investment funds among different projects but also whether to increase investment spending at the expense of other types of discretionary outlays.

To help the Congress with these decisions, this study examines the effect on the economy and on other aspects of national welfare of three broad classes of federal investment spending: physical infrastructure, including transportation and environmental facilities; "human capital," including programs that increase the skills and productive knowledge that people bring to their jobs; and "intangible" capital, such as research and development (R&D). One of the main implications of the report is that public-sector investments in each of these areas, chosen carefully, can play a role in promoting economic expansion, as can other federal policy initiatives such as those to reduce the budget deficit or sharpen incentives for productive activities.

Investment is widely agreed to be one of the principal sources of economic growth. Financed by the savings of households, businesses, governments, and foreigners, investment expands the stock of capital that is available for use in producing goods and services. With more capital, and therefore more production, both income and the standard of living rise. Although these arguments are familiar by now, many who hear them assume that they apply primarily, or even exclusively, to investment by the private sector. The evidence surveyed in this report shows that public-sector capital also can be important in expanding the economy's productive capacity.

Since federal investments can contribute to the expansion of the economy much as private investments do, many economists argue that they ought not to be counted in the federal deficit. Pressures to reduce the budget deficit arise in part because deficits are conventionally treated as factors that reduce national saving and investment. According to the conventional view, deficits divert the savings of households and other sectors to an unproductive use--government consumption--instead of leaving them for investment by the private sector. However, since public investment can be economically equivalent to private investment, some economists argue that it should be excluded from the measured federal deficit so it will not be treated as detracting from national saving and investment. Indeed, economic models show that expanding federal investment can lead to increased gross national product (GNP) even when it is financed through borrowing. By contrast, expanding the federal deficit through tax reductions or increased noninvestment spending can eventually reduce GNP because it cuts the flow of savings available for investment.[1]

Rather than examining the possibility of expanding federal investment through additional borrowing, or of changing the budgetary treatment of investment, the objectives of this study are more basic: to show which federal outlays can be considered to be investments, to discuss ways of evaluating how strong their likely contributions to the economy are, and to summarize the available evidence on what types of federal investment are likely to be most valuable to the nation at this time. The study examines trends in federal investment spending and the rationales for that spending, describes economic criteria for choosing an optimal level of public investment, and reviews the findings of studies that have evaluated the contribution of public investment to economic output.

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1. See Congressional Budget Office, "Comparative Economic Effects of Increased Public Investment and Reduced Payroll Taxes," CBO Staff Memorandum (April 1991). For discussion of related issues in the measurement of the deficit, see Congressional Budget Office, *The Federal Deficit: Does It Measure the Government's Effect on National Saving?* (March 1990).

Although the federal expenditures discussed in this study all offer the possibility of increasing economic efficiency and output, many also have been designed to serve other national needs that may not contribute to measured economic progress. For example, some physical investments and many expenditures on human resources are intended to promote noneconomic objectives such as a more equal access to public transportation, health care, and educational opportunities. This study examines principally how federal spending affects economic performance, and does not attempt to evaluate the success of these programs in furthering social goals. Moreover, the study makes only limited efforts to compare federal investments with other ways in which federal policies might influence economic performance. (For example, both the rate of capital formation and the supply of labor are affected to one degree or another by the federal tax code, by federal deficits, by regulations on workplace safety and environmental protection, by the legal rules of contract, and by monetary and trade policies.)

Most broadly, this study finds that spending in each of the public capital areas considered may yield returns greater than the average rate of return to private investment. Such high returns, however, can be expected only on carefully selected spending projects. Little empirical support exists for some analysts' claim that across-the-board increases in certain categories of public capital spending would yield rates of return that are greater, on average, than the return to private-sector investment.

RATIONALES FOR FEDERAL CAPITAL SPENDING

Most federal capital spending programs supplement similar investments by the private sector and by state and local governments. Two rationales lie behind federal investment programs. First, many programs were designed in part to remedy some form of "market failure," in which private markets fail to provide households, businesses, and state and local governments with the incentives needed to produce enough capital spending to maximize economic welfare. Second, most federal investments are also intended to advance various social goals.

One important market failure occurs when expenditures yield benefits that go beyond, or "spill over," the purview of individual subnational levels of government or companies. As a result, these entities are unlikely to spend as much on such projects as would be beneficial for society as a whole unless the government intervenes. For example, local governments may not spend enough on roads because some of the benefits go to taxpayers of other jurisdictions. The needs of those individuals are not represented in local decisionmaking and are unlikely to be fully satisfied through decisions by local governments. When the benefits from investment spread beyond the reach of subnational governments, the federal government must ensure investment sufficient to satisfy national needs. Similarly, companies may not invest as much in the training of their workers as society needs because they cannot be sure that these individuals will not quit and take their skills elsewhere, giving another employer the benefit of their training. Or, companies may not invest enough in research and development from society's point of view, in part because there is no guarantee they will control the commercial benefits stemming from the resultant products or procedures. In such cases, government--in many cases, the federal government--may be called upon to ensure that enough training or research is carried out.

The problem of risk also contributes to market failure. For example, individuals may not be able to borrow enough in private financial markets to support their own education because they have no physical or financial assets to use as collateral to protect private lenders against the risk of default. As a result, government often steps in to ensure that sufficient educational financing is available. Similarly, the private sector may not always be well equipped to support the risk involved in research and development. Individual R&D projects are quite risky, but when many projects are mounted at once, the risks can be pooled and the risk of the overall program of research reduced. Yet only governments, or a few large companies, are able to carry out large enough R&D programs to realize the risk-reducing benefits that large-scale efforts make possible.

To be sure, market failures and other narrowly economic arguments do not provide the only rationale for federal investment. Many federal programs are justified first by social goals, rather than by economic considerations. In particular, many human resource programs are intended primarily to improve the health, income, education, or other opportunities of relatively disadvantaged people. In many other cases, federal programs have been designed to standardize the level of some good or service throughout the country and for all segments of society. Federal involvement in highway development is partly justified by the sense that all regions of the country should have equal mobility; similar arguments help explain the federal role in water quality projects.

HOW MUCH PUBLIC INVESTMENT IS ENOUGH?

Federal spending for investment generally can be increased only by diverting resources from other uses--either from investment by the private sector or from consumption by the public or private sectors.[2] To the extent that the benefits from federal investment can be quantified, a simple rule can be used to weigh the trade-offs among different types of spending: greater federal investment will increase aggregate welfare as long as the extra dollar invested yields benefits that are greater than those derived from alternative uses of the funds. The added capital spending, in other words, must yield not only a positive return, but a return greater than that which could be achieved by using the funds for some other purpose.

To implement this rule, both the returns to public capital spending and the returns from alternative types of outlays must be measured. Two kinds of economic studies have been used to evaluate the relative returns to public investments; the later chapters of this study present an extensive survey of the results from both approaches. One method, the production-function approach, examines economic data on the relationship between private output and broad classes of public investment. The other approach, cost-benefit analysis, analyzes more disaggregated data to estimate the benefits and costs of individual projects or classes of projects, either retrospectively or prospectively. Although these two approaches are variations on the same theme, each has distinct strengths and weaknesses.

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[2] Such trade-offs between the amounts of resources that are available for different purposes may not exist when there is significant unemployment in the economy. Then, resources can be devoted to federal investment without reducing those available to other purposes simply by putting previously idle resources to work. Generally, however, few idle resources are available, and sacrifices will be needed to allow federal investment to increase.

The Production-Function Approach

The most comprehensive assessment of the contribution of public investment to economic growth is given by production-function studies. These studies generally provide a statistical estimate of a production function, showing the levels of various inputs--such as labor, private capital, and public capital--needed to produce specific amounts of output. The analysis can be done at any level of aggregation--for individual firms, for economic sectors, or for the economy as a whole.

The chief virtue of production-function studies is the scope they bring to the problem of planning public expenditures to promote economic growth. By examining the effects of an entire category of investment, such as federal outlays for physical infrastructure, these analyses can indicate what combination of private and public capital might expand private output most efficiently.

Three aspects of production-function studies, however, limit their usefulness as a guide to public policy. The first problem with these studies is their very breadth. In many cases production-function studies must be conducted with quite limited data. Largely as a result of these data limitations, the extent to which changes in economic output result from changes in public capital or from changes in other forces has been difficult to distinguish clearly. Even if these statistical problems could be overcome, the broad scope of production-function studies would make them poorly suited for the task of assessing the relative efficacy of the many investments competing for public funds.

A second problem with production-function studies is that they examine only relationships that prevailed in earlier periods. Their relevance to setting policy thus hinges on whether the conditions that determined the productivity of public investments in the past will still exist in the future. In some cases both the costs and benefits of public capital outlays can change dramatically over time. Such potential changes can be seen most clearly, perhaps, in the case of transportation facilities. The initial investments in a transportation network will provide a given level of transportation services far more cheaply than will subsequent investments in roads that fill in the basic transportation network. Thus, some analysts have found that although the rapid growth in highway infrastructure between 1950 and 1973 appears to have yielded substantial economic benefits, the highway investments made during the subsequent decade had a much smaller effect on transportation output.[3] The changing returns to investment can also be seen in spending for defense-related research and development. Defense R&D hastened the development of jet engines and computers, yielding big payoffs from commercial as well as defense-related applications. Yet many observers believe that the potential commercial applications of defense R&D have diminished over time. Production-function studies give little indication of the changing nature of public investment opportunities.

A final drawback of production-function studies is that they can quantify only the economic effect of public capital investments. These studies do not capture the extent to which different public investments provide nonmarketed benefits or further those social goals that are not reflected in measured GNP. Yet as noted above, most federal capital spending has been designed in part to further various noneconomic goals. Even if these programs were found to have little quantifiable effect on measured economic output, they might nonetheless make important contributions to social well-being.

The Cost-Benefit Approach

Analysts also evaluate public investments by comparing the costs and benefits of individual projects or classes of projects. For each investment project contemplated, the cost-benefit analyst attempts to identify specific expected benefits. Like production-function studies, cost-benefit analysis first involves measuring the project's economic benefits, such as increased production of marketable goods and services. Any nonmarketed benefits are estimated and added in. A principal benefit from improved roads, for example, is the lower travel times that they make possible. Similarly, the improved water quality that follows the construction of wastewater treatment facilities provides benefits in such nonmarketed forms as better health, better recreation opportunities, and preserved wildlife. Most human resource programs also promote goals that are not directly related to economic benefits. A substantial fraction of the benefits from the Job Corps program, for example, occurs as a reduction in crime. The cost-benefit analyst attempts to assign dollar values to each of these nonmarketed benefits.

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[3] The principles governing the cost of, and return to, transportation investments are described in Clifford Winston, "Conceptual Developments in the Economics of Transportation: An Interpretive Survey," *Journal of Economic Literature* (March 1985), pp. 57-94, and the literature cited therein. The changing returns to highway spending are examined in Theodore E. Keeler and John S. Ying, "Measuring the Benefits of a Large Public Investment: The Case of the U.S. Federal-Aid Highway System," *Journal of Public Economics*, vol. 36 (1988), pp. 69-85; and in Congressional Budget Office, *Federal Policies for Infrastructure Management* (June 1986).

In parallel fashion, the cost-benefit analyst estimates both marketed and nonmarketed costs associated with a project, and then calculates an overall rate of return. For example, a study of airport expansion might contain estimates of the additional costs imposed on the airport's neighbors because of noise--a factor not reflected in narrow economic measures. For each period of the project's life, the net benefits are then computed as estimated benefits less estimated costs. The rate of return on the project can be computed from the stream of net benefits over the project's lifetime.[4] Comparing rates of return helps policymakers judge whether the public investment they are considering is more productive than alternative uses of resources, such as investments by the private sector.

Another, similar method of carrying out cost-benefit analyses also begins by assembling estimates of the net costs and benefits of the project in different years. Instead of computing a rate of return for comparison with the return on alternative uses of resources, however, this approach introduces a rate of return on alternatives, called a discount rate, into the calculation. The discount rate is used to scale back or "discount" all costs and benefits projected for years after the first year so that they are instead expressed in terms, called "present values," that are economically comparable with values occurring in the first year. If the present value of benefits exceeds the costs, the policymaker can infer that the rate of return on the project exceeds that on alternative projects as represented by the discount rate.[5] For technical reasons, estimating the expected present value of a prospective project, rather than its expected rate of return, is the best way to evaluate it.

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[4] The rate of return implied by a stream of net benefits may not be unique. See Richard W. Tresch, *Public Finance: A Normative Theory* (Plano, Texas: Business Publications, Inc., 1981), Chapter 23; and Martin S. Feldstein and John S. Flemming, "The Problem of Time Stream Evaluation: Present Value versus Internal Rates of Return Rules," *Bulletin of Oxford University Institute of Economics and Statistics*, 26 (1964), pp. 79-85.

Cost-benefit studies offer two advantages over production-function studies. First, by including some nonmarketed costs and benefits, the cost-benefit approach can provide an estimate of a project's effects on aggregate welfare, rather than on national income alone. Second, by adopting a narrower focus, cost-benefit studies are able to provide a more thorough analysis of specific projects. As a result, such studies are more likely to reflect the value of particular projects, taking into account the specific circumstances that underlie them. This feature of the cost-benefit approach allows it to show how investment returns diverge widely both across and within specific capital programs. Moreover, in comparison with production-function studies, the more detailed approach of cost-benefit analysis can better reflect the extent to which returns to public investment vary over time.

Cost-benefit studies also have their problems, however. The value of individual studies is sometimes questioned because of the difficulties of choosing an appropriate discount rate, for example, or of assigning dollar values to nonmarketed costs and benefits such as crime, noise, or life expectancy.[6] Because individual studies take account only of those costs and benefits that the analyst identifies in advance, they cannot show the effects of any spillovers or other indirect costs and benefits not anticipated during the design of the study. Despite their limited scope, moreover, cost-benefit studies can be expensive and time consuming.

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[5] For a detailed comparison of present-value and internal-rate-of-return approaches, see Feldstein and Flemming, "The Problem of Time Stream Evaluation."

[6] A thorough review of cost-benefit analysis, including an examination of various technical issues, can be found in Tresch, *Public Finance*; and Edward M. Gramlich, *A Guide to Benefit-Cost Analysis* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1990).

The rest of this report surveys the results of production-function and cost-benefit studies of federal investments in a variety of areas. Although these results lead to some useful generalizations, they should be approached with caution for several reasons. Both production-function and cost-benefit studies suffer from technical problems, as this discussion has already pointed out. Equally important, however, is the fact that not enough studies are available to represent a thorough investigation of the potential returns to all possible types of new federal investments. Few studies have been done in some areas. Although other areas have been evaluated more extensively, the studies may contain results with significant margins of error. In short, the technical evidence conveyed by this report provides only a rough guide to the economic effects of federal capital spending.

CHAPTER II

FEDERAL INVESTMENT IN PHYSICAL INFRASTRUCTURE

Since the late 1700s, the federal government has invested in physical capital, both to promote economic growth and to further various social goals. The earliest federal investments were for transportation infrastructure, such as roads, inland waterways, ports and harbors, and railroads. More recently, federal infrastructure investments have also included subsidies for aviation, multipurpose dams and other water projects, and environmental infrastructure such as wastewater treatment facilities. In 1990, the federal public works investment totaled more than $26 billion, and accounted for more than 40 percent of infrastructure investment by all levels of government.[1]

Federal infrastructure investments are important to private economic output in a number of ways. First, the productivity of private inputs can be enhanced by public capital. The usefulness of privately owned cars and trucks, for example, depends on networks of public roads and bridges. Private aircraft use public airports and air traffic control systems. Private ships and barges rely on the public locks and dams of the inland waterway system and on public port and harbor facilities. And agriculture and industry depend heavily on public facilities both for water and treatment of waste by-products.

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[1] The federal infrastructure investment considered in this chapter totaled $24.1 billion in 1989. This amount includes $20 billion for grants-in-aid to state and local governments and $4.1 billion in direct spending. The historical tables in the federal budget, in contrast, list about $38 billion in major physical capital investment for 1989, including $24 billion in grants-in-aid and about $14 billion in direct outlays. The difference between grants-in-aid considered here and those listed in the budget stems mostly from the exclusion here of funds for regional and community development programs. The direct outlays considered here consist almost entirely of outlays for water resources. The remaining $10 billion listed in the budget as direct nondefense physical investment consists primarily of spending for "other" ($2.6 billion), the National Aeronautics and Space Administration ($2 billion), energy ($1.9 billion), Department of Veterans Affairs hospitals ($1.1 billion), and the Postal Service ($0.9 billion).

In addition to these direct expenditures, the federal government also subsidizes state and local infrastructure investment through several tax expenditures, such as the deductibility from federal income tax of interest earned on state and local bonds. This paper does not evaluate these tax expenditures.

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Public capital can also reduce the amount of private inputs needed for a given level of output. More efficiently designed and better maintained roads reduce wear and tear on private vehicles. By cutting travel time, better roads lower the amount of labor required for shipping. Shorter and more certain shipping times allow inventories to be reduced, resulting in lower inventory carrying costs. Similar arguments can be made for other parts of the transportation network.

Finally, publicly provided infrastructure may have much the same influence on private output as does privately provided infrastructure, for the distinction between public and private infrastructure in many cases reflects institutional and political choices, not economic imperatives. All of the transportation and environmental services provided by public infrastructure--whether aviation, rail, mass transit, wastewater treatment, or anything else--can be supplied by either the public or private sector. The choice of whether to furnish these services through the public sector or to allow their development as privately owned industries has been made differently in different countries, and in different periods.[2]

These general observations suggest that public capital is important to the private economy, but leave open two important policy issues. First, should the federal government make investments in public infrastructure or instead leave such investments solely in the hands of state and local governments? Second, if federal investments are undertaken, how much investment is enough? General observations about the potential effect of public capital on private output offer policymakers little specific guidance about the amount of public capital needed to maximize economic activity. Moreover, some infrastructure programs are intended to promote goals other than expanding the economy. It is difficult to assess how well different amounts and types of public infrastructure meet such goals.

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[2] See European Conference of Ministers of Transport, *Roundtable 81: Public and Private Investment in Transport* (Paris: Organization for Economic Cooperation and Development, 1990), pp. 16-21; Robert W. Poole, Jr., "Resolving Gridlock in Southern California," *Transportation Quarterly*, 42 (1988); Jack Donahue, *The Privatization Decision: Public Ends, Private Means* (New York: Basic Books, 1989), p. 76; and Jose A. Gomez-Ibanez and John R. Meyer, "The Prospects for Privatizing Infrastructure: Lessons from U.S. Roads and Solid Waste," in Alicia H. Munnell, ed., *Is There a Shortfall in Public Capital Investment?* Conference Series No. 34 (Boston: Federal Reserve Bank of Boston, June 1991).

This chapter addresses these issues by reviewing the nature and size of current federal infrastructure programs, the rationales for federal spending, and evidence on the relation between public infrastructure investments and private economic performance. The chapter's main purpose is to review recent evidence on the extent to which additional federal spending on infrastructure would promote additional economic activity. In keeping with the approaches outlined in Chapter I, evidence is summarized from both production-function studies and cost-benefit analyses on whether additional public capital is likely to be more productive than additional private capital.

Much of the empirical evidence reviewed in this chapter suggests that additional public infrastructure investments will contribute to private economic output. The magnitude of that contribution, however, remains uncertain. The evidence does not support claims that private economic output currently can be stimulated more effectively through broad-based increases in public infrastructure spending than through greater investments in private capital. Empirical studies instead show wide variation in the returns to public infrastructure, with a limited set of such investments appearing to offer high economic returns. In many cases, substantial economic benefits also may be achieved through the more efficient use of existing infrastructure assets.

TRENDS IN FEDERAL SPENDING ON INFRASTRUCTURE

Federal investments in infrastructure grew rapidly between 1955 and 1980, and have followed a slight downward trend since then. Table 1 shows that, adjusted for inflation, federal infrastructure investments rose from $6.0 billion (in 1990 dollars) in 1956 to $17.3 billion by 1960, and then rose fairly steadily to $29.4 billion by 1980. Since then, real infrastructure investments have fluctuated between roughly $29 billion and $24 billion annually. These investments totaled $26.2 bil-

TABLE 1. FEDERAL INFRASTRUCTURE INVESTMENT
(In billions of 1990 dollars)

							Infrastructure Investment	
Year	Highways	Transit	Sewage Treatment	Aviation	Water Programs	Rail	Total	As a Percentage of All Federal Outlays
1956	3.5	a	a	0.1	2.3	a	6.0	2.0
1957	4.3	a	a	0.2	2.5	a	7.0	2.4
1958	6.8	a	0.1	0.4	3.1	a	10.4	3.3
1959	11.7	a	0.2	0.6	3.2	a	15.6	4.4
1960	13.2	a	0.2	0.7	3.3	a	17.3	5.0
1961	11.8	a	0.2	0.8	3.9	a	16.8	4.6
1962	12.5	a	0.2	0.8	4.4	a	17.9	4.6
1963	13.3	a	0.2	0.7	4.6	a	18.8	4.8
1964	15.8	a	0.3	0.6	4.6	a	21.4	5.1
1965	17.1	a	0.3	0.6	4.6	a	22.7	5.5
1966	16.5	0.1	0.3	0.8	4.9	a	22.6	5.1
1967	15.9	0.2	0.4	0.4	4.9	a	21.7	4.2
1968	15.9	0.3	0.5	0.5	4.6	a	21.8	3.9
1969	15.1	0.5	0.6	0.6	4.1	a	20.9	3.8
1970	14.6	0.4	0.7	0.6	3.6	a	20.0	3.7
1971	14.3	0.6	1.6	0.6	4.2	a	21.3	4.0
1972	13.5	0.8	1.3	0.9	4.5	a	21.0	3.9
1973	13.0	1.0	1.9	1.4	4.3	a	21.6	4.1
1974	11.0	1.2	4.0	1.1	4.6	0.1	22.1	4.2
1975	9.7	1.8	4.3	1.0	4.5	1.0	22.4	4.1
1976	12.5	1.9	5.3	0.9	4.7	1.5	26.8	4.6
1977	11.4	2.5	7.2	1.0	5.2	1.5	28.8	4.8
1978	10.2	2.3	6.0	1.4	5.2	1.3	26.3	4.2
1979	10.7	2.6	6.3	1.2	5.0	1.5	27.4	4.5
1980	12.2	2.7	6.5	1.2	5.1	1.6	29.4	4.7
1981	11.2	3.3	5.5	1.0	4.6	0.6	26.2	3.9
1982	9.6	3.2	5.2	0.8	4.5	0.7	24.0	3.4
1983	10.7	3.4	4.1	1.0	4.0	0.5	23.6	3.0
1984	12.4	3.7	3.5	1.2	4.0	a	24.4	3.0
1985	14.4	2.7	3.7	1.4	4.2	0.4	26.8	3.1
1986	15.4	3.0	3.8	1.8	5.0	0.1	29.2	3.3
1987	13.6	2.8	3.2	2.0	3.5	0.1	25.2	2.9
1988	14.5	2.5	2.6	2.0	3.9	a	25.5	2.8
1989	13.5	2.7	2.6	2.6	3.2	a	24.6	2.6
1990	14.0	3.1	2.6	2.7	3.7	a	26.2	2.5

SOURCE: Congressional Budget Office using data from the *Budget of the United States Government*, various years, and from unpublished Office of Management and Budget data.

a. Less than $50 million.

lion in 1990, nearly the same in real terms as in 1978.[3] As a percentage of total federal outlays, capital infrastructure spending rose from 2.0 percent in 1956 to a high of 5.5 percent in 1965, and then fell more or less steadily to 2.5 percent in 1990.

Highways

From 1956 through 1970, trends in federal infrastructure outlays mirrored trends in federal highway spending (see Figure 1). Following passage of legislation authorizing construction of the Interstate Highway System, inflation-adjusted federal highway investments rose from $3.5 billion in 1956 to $13.2 billion in 1960. Real outlays peaked in 1965 at $17.1 billion, about 75 percent of all federal capital infrastructure spending. After falling steadily between 1966 and 1975, real capital outlays for highways have fluctuated around a slight upward trend through the present. In 1990, federal capital highway spending totaled $14.0 billion, more than 50 percent of all federal infrastructure investments. Nearly all federal highway outlays are funded by the Highway Trust Fund, which receives revenues from several excise taxes--the most important being the federal tax on gasoline.

The bulk of federal highway spending takes the form of grants to states for the construction and reconstruction of roads in the Federal-Aid Highway System.[4] The principal federal programs include:

o *Construction of Interstate Highways.* Federal grants provide states with up to 90 percent of the costs of constructing roads in the Interstate Highway System. More than 99 percent of the Interstate System has been completed. Funds to complete the remaining portions will be obligated by the end of 1992.

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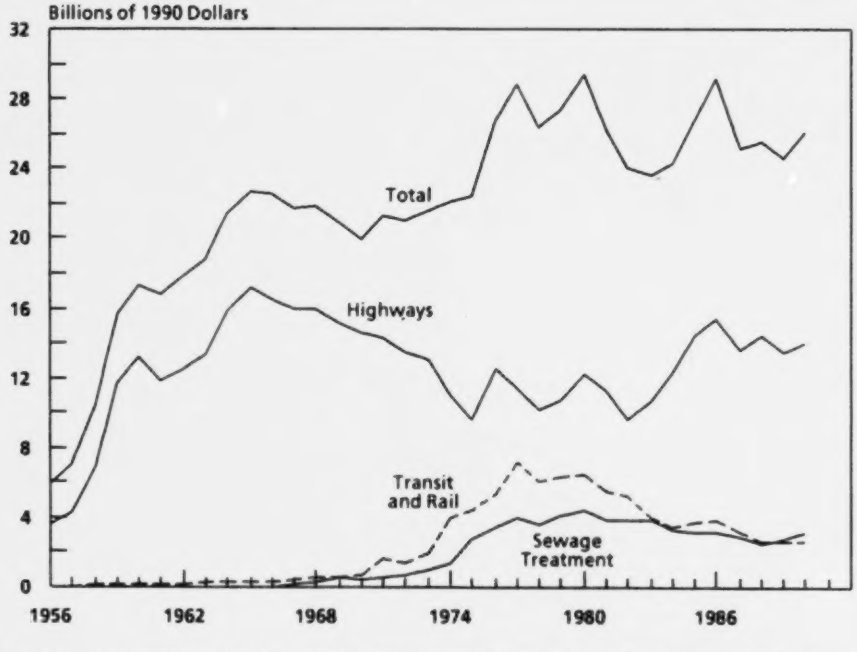
[3] Throughout this period, about three-quarters of federal infrastructure investments have taken the form of grants or loans to state and local governments; the remainder have been direct federal purchases. For an overview of federal infrastructure programs, see Congressional Budget Office, *New Directions for the Nation's Public Works* (September 1988); Congressional Research Service, *Understanding U.S. Transportation Program Finances* (August 1990); and Congressional Research Service, *Federal Aid to Domestic Transportation: A Brief History* (August 1988).

[4] The Federal-Aid Highway System is described in Federal Highway Administration, *Highway Statistics, 1988* (1989).

- *Maintenance and Rehabilitation of Interstate Highways.* Federal grants cover 90 percent of project costs for resurfacing, restoring, rehabilitating, and reconstructing (4R) Interstate highways. In states with no Interstate 4R needs, these funds may be used on other primary roads.

- *Construction of Other Primary Roads.* Federal grants pay up to 75 percent of construction costs on the non-Interstate roads in the primary system.

Figure 1.
Federal Capital Spending for Selected Infrastructure Categories, 1956-1990



SOURCE: Congressional Budget Office using data from the Office of Management and Budget.

- *Secondary and Urban Roads.* Federal grants can be used to pay up to 75 percent of construction or expansion costs for secondary and urban roads in the Federal-Aid Highway System.

Most other federal highway funds benefit public roads generally, and are not restricted to roads in the Federal-Aid Highway System. The largest of these more broadly based federal programs provides 80 percent of bridge replacement or rehabilitation costs.

This year the Congress will consider legislation to reauthorize federal surface transportation programs. The Administration's reauthorization proposal would significantly change many features of current federal highway policy. Among other things, the bill would create new categories of highways, change the share of highway costs paid by the federal government, allow greater use of tolls, and expand the highway research program.

Mass Transit

Despite the decline in real highway spending, total federal investments in physical infrastructure increased during the 1970s, driven by sharply higher federal funding for transit and wastewater treatment programs. In real terms, federal investments in transit rose from $0.4 billion in 1970 to $1.8 billion in 1975, $2.7 billion in 1980, and $3.7 billion in 1984. Federal capital transit outlays then fell to $2.5 billion before rising to $3.1 billion in 1990.

Most federal transit grants are made to local governments and subsidize both capital projects and operating costs.[5] These grants principally support purchases of new buses, bus rehabilitation, maintenance facilities for buses, construction of new rail systems, and modernization and extension of existing rail systems. Most mass transit funds are distributed through two programs, Section 9 (and 9B) formula grants and Section 3 discretionary grants. Formula grants are distributed to "urbanized areas" according to population, population density, and various measures of transit service and use. Federal formula grants subsidize up to 80 percent of the cost of local transit capital projects and up to 50 percent of transit operating costs. In 1990, budget authority of $0.9 billion, about 53 percent of the total budget authority for Section 9 and 9B formula grants, was made available for capital subsidies. An additional $1.0 billion in budget authority was provided for Section 3 discretionary grants. These grants subsidize only capital projects and cover up to 75 percent of project costs. At least 40 percent of these funds must be used for modernizing rail systems, at least 40 percent for bus and bus-related projects, and at least 10 percent for constructing new systems.

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[5] Mass transit programs are described further in Congressional Budget Office, *New Directions*; and in Congressional Research Service, *Understanding U.S. Transportation Program Finances.*

Funds for transit formula grants come from both the general fund and the 1.5 cents per gallon of the 14-cents-per-gallon gasoline tax that are deposited in the transit account of the Highway Trust Fund. Discretionary grants are financed entirely with funds from the mass transit account of the Highway Trust Fund.

The Administration's reauthorization proposal for surface transportation would substantially change the structure of federal mass transit programs. Among other things, the bill would shift funding from operating to capital assistance and from discretionary to formula grants. In addition, most transit spending would be financed from the transit account of the Highway Trust Fund.

Wastewater Treatment

The rise in capital infrastructure spending during the 1970s also reflected a dramatic expansion of federal subsidies for the construction of municipal wastewater treatment facilities. The 1972 Clean Water Act set new and far stricter standards for municipal wastewater treatment. To help localities comply with the new requirements, the federal matching rate for local spending on the construction of wastewater treatment plants was increased from 50 percent to 75 percent, and inflation-adjusted appropriations for construction grants rose from $1.3 billion in 1972 to $7.2 billion in 1977.

The expanded federal presence was intended to be temporary. In 1981, the Congress began the process of returning to states and their localities complete financial responsibility for managing water quality. The Clean Water Act Amendments of 1987 were designed to complete the transition to state and local self-sufficiency. The amendments require that the municipal construction grants program be phased out by the end of 1991. In its place, the amendments establish a temporary federal program to provide seed money for state revolving loan funds (SRFs). For each dollar in federal capitalization grants, a state must provide 20 cents to its SRF. These funds provide low-interest loans for local efforts to control water pollution; loan repayments produce a self-sustaining source of money to finance local construction after the capitalization grants expire at the end of 1994. In 1990, federal subsidies for the construction of wastewater treatment plants totaled $2.6 billion.[6]

Aviation

Between 1960 and 1981, real federal capital spending for aviation was erratic, reflecting the lumpy and infrequent nature of investments for the expansion of airports. But later, as the deregulation of airlines led to consistent and substantial growth in air travel, real federal capital spending for aviation rose steadily from $0.8 billion in 1982 to a high of $2.7 billion in 1990.

Most federal funds for aviation capital investment come from the Airport and Airway Trust Fund. The trust fund receives revenue from aviation-related excise taxes, principally on sales of passenger tickets. In 1990, about one-half of capital outlays for aviation supported efforts by the Federal Aviation Administration (FAA) to modernize and expand the national air traffic control system, and FAA programs for research, engineering, and development. The remaining federal capital spending was disbursed as grants from the Airport Improvement Program (AIP). AIP grants subsidize the planning and construction of "airside" improvements (such as runways and taxiways, public terminals, and noise- and safety-related projects) and for planning and coordination with other local airports. AIP funds are distributed through both formula grants and discretionary grants. Large commercial service airports receive up to 49.5 percent of the funds as entitlements based on annual passenger enplanements; states receive 12 percent of funds for distribution to general aviation airports; and the Secretary of Transportation distributes at least 38.5 percent of funds as discretionary grants. One of the purposes of discretionary grants is to assure that at least 10 percent of all AIP funds goes to reliever airports, 10 percent goes to noise abatement projects, 2.5 percent goes to small airports, and 0.5 percent is used for airport planning grants.[7]

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[6] A history of the federal role through 1986 can be found in Environmental Law Institute, *The Law of Environmental Protection* (New York: The Institute, 1987); the 1987 Clean Water Act Amendments are discussed in Bureau of National Affairs, *Environmental Reporter*, vol. 18, no. 19 (1987), Part II.

The distribution of funds from the AIP program may be affected by provisions of the Aviation Safety and Capacity Expansion Act of 1990. That act allows airports to charge a head tax, or "passenger facility charge," of up to $3 per passenger.[8] Airports that impose a head tax will forfeit 50 percent of the AIP funds they would otherwise receive. For the large airports that handle a majority of passengers, revenues from the head tax are expected to far exceed the forgone AIP grants. Therefore, as large airports impose the head tax, more AIP funds should become available for smaller airports.

Water Resources

Real capital outlays for water programs rose from $2.3 billion in 1956 to $5.2 billion in 1977, and have fallen since then to $3.7 billion in 1990. Unlike other federal funding for infrastructure, most capital outlays for water resources are direct federal purchases.[9]

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[7] More detailed descriptions of federal programs supporting the nation's airport and airway system can be found in Congressional Budget Office, *Policies for the Deregulated Airline Industry* (July 1988); CBO, *The Status of the Airport and Airway Trust Fund* (December 1988); CBO, *New Directions*; and Congressional Research Service, *The Airport Improvement Program: Selected Economic and Legislative Issues* (October 1988).

[8] Before any airport can impose a head tax, the Secretary of Transportation must issue a final rule on procedures for the Department of Transportation's review of local airport noise restrictions. See General Accounting Office, *Airline Competition* (December 1990).

[9] Federal water programs are described in Congressional Budget Office, *New Directions*; Congressional Research Service, *Water Resources Development Act: Implementing the Omnibus Project Reforms* (August 1990); and Congressional Research Service, *Understanding U.S. Transportation.*

Two agencies--the Army Corps of Engineers (the Corps) and the Bureau of Reclamation in the Department of the Interior--account for the bulk of federal spending for water programs.[10] Both agencies undertake water resource projects for flood control, water supply, and hydroelectric power. In 1990, these agencies together spent approximately $1.3 billion on such multipurpose water projects. The responsibility for most other investments in water transportation--including the construction and maintenance of both inland waterways and ports and harbors--lies with the Corps alone.

The Corps is responsible for building and maintaining nearly all inland and intracoastal waterways used for commercial navigation. In 1985, waterways carried about 15 percent of all intercity freight movement. In 1990, the Corps spent about $0.4 billion on capital projects for inland and intracoastal waterways.

Until 1978, taxpayers generally bore the entire cost of building the inland waterway system, but since then users have borne an increasing share of the system's costs. The Inland Waterways Revenue Act of 1978 introduced a phased tax on fuel consumed by commercial barges using most segments of the inland waterway system. The inland waterway fuel tax is scheduled to rise to 20 cents per gallon by 1995, and is intended to finance one-half of future construction of inland waterways.

The Corps also subsidizes deep-draft port and harbor projects, including dredging navigation channels and constructing general navigation works such as breakwaters and jetties. In 1990, the Corps spent about $130 million on such capital projects. The 1986 Water Resources Development Act required for the first time that the state or local government sponsoring a navigation project pay a portion of initial dredging costs. The nonfederal share is between 10 percent and 50 percent, depending on the depth of the dredging. The act explicitly allows the project sponsor to recoup its contribution by imposing port user fees.

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10. Other programs provide funding for the Maritime Administration, the Coast Guard, and local water supply projects.

Railways

Except during the late 1970s and early 1980s, federal capital spending for railways has been relatively small. Throughout much of the twentieth century, federal subsidies for railroads took the form of loan and loan guarantee programs that involved only small federal outlays. Following the creation of Amtrak and Conrail in the early 1970s, however, federal capital spending for railroads rose from $0.1 billion in 1974 to $1.6 billion in 1980. Federal rail investments then fell as Conrail returned to profitability in 1981, and returned to private ownership in 1987. Subsidies to Amtrak account for most of the remaining federal capital spending on railways. Outlays for Amtrak capital spending totaled approximately $65 million in 1990.

RATIONALES FOR FEDERAL INVESTMENTS IN INFRASTRUCTURE

Each of the nation's infrastructure programs was created to serve many purposes, but three motivations for federal involvement were paramount. First, federal cost-sharing was designed in part to increase state and local investment in infrastructure by compensating states and localities for the spillover effects of infrastructure investments. Many kinds of infrastructure--interstate highways, the national system of airports and air traffic control, inland waterways, and others--benefit residents outside the jurisdiction providing the facility. When a community that pays for a facility can recover the cost of providing services to nonresidents (through user fees, for example), no federal intervention may be necessary. But when a community receives only a fraction of the benefits from a facility, yet must pay all of the associated costs, it has no incentive to provide the level of services most beneficial for the nation as a whole. By paying the portion of state and local expenditures that corresponds to the spillover benefits, the federal government can encourage states and localities to make appropriate investments.

Second, most federal transportation programs were set up to minimize the costs of providing integrated regional or national transportation networks. The programs in highways, airports, air traffic control, and inland waterways were undertaken at the federal level in part because no other jurisdiction could plan a system of such facilities from a national perspective. Through its role as financier, the federal government was able to coordinate and centralize the provision of some public works, reducing duplication and unnecessary investment.

Third, federal infrastructure programs have been designed not simply to provide the public works needed for national economic growth, but also to further a variety of social goals. The mass transit, aviation, and highway programs, for example, were all conceived in part as ways to increase the mobility of the population and to connect the various regions of the country. Similarly, federal subsidies for the construction of local wastewater treatment plants were designed to help achieve national standards for water quality. Finally, many infrastructure projects--such as the Interstate Highway System and the system of inland waterways--were designed in part to further national defense. In this sense, infrastructure programs have actively pursued the added benefits of meeting social needs while enabling economic expansion.

THE ECONOMIC RETURN ON FEDERAL INFRASTRUCTURE INVESTMENT: EVIDENCE FROM PRODUCTION-FUNCTION STUDIES

Many studies, using the production-function approach described in Chapter I, have tried to quantify the effect of public capital spending on private economic performance. These studies generally estimate an aggregate "production function," which shows the levels of various inputs--such as labor, private capital, and public capital--needed to produce specific amounts of private output. The estimated production function can be used to compare the effects on output of added public and private investment. In particular, the production function provides an estimate of whether private output would expand more from additional spending on public capital or from an equal amount of additional investment in private capital.

Results from macroeconomic studies have varied widely. Although many have found statistical evidence that public capital influences private output, the magnitude of public capital's influence is usually uncertain and quite small. Changes in private output are far better explained by changes in the amount and quality of the labor and private capital employed.

Studies with Aggregate U.S. Data

One set of studies--those using data for the U.S. economy as a whole--reaches sharply different conclusions about the impact of public capital on private economic growth, and consequently about the desired level of public capital spending. In a widely noted series of papers, David Aschauer has presented empirical evidence suggesting that underinvestment in public capital slowed the growth of private economic output throughout the 1950-1985 period. Aschauer's findings indicate that even during the 1950-1972 period, when growth in U.S. productivity exceeded its historical level, stocks of public capital were well below their economically optimal levels. Given current public capital stocks, added public capital spending would increase the output of private firms more than three times as much as would an equal dollar increase in those firms' own capital stock.[11]

The general implication of these results--that public capital increases private economic output--accords with economic theory and with other empirical studies. Yet the magnitude of the effect ascribed to public capital invites skepticism, arising principally from two concerns. The first is that the statistical results are not robust--small changes in the data or statistical techniques used can produce relatively large changes in the estimated productivity of public capital. The second concern is the lack of corroborating evidence: nearly all other empirical research, including cost-benefit studies, finds that private output is influenced far more by investments in private capital than by investments in public capital.[12]

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[11] See David A. Aschauer, "Is Public Capital Productive?" *Journal of Monetary Economics*, vol. 23 (1989), pp. 177-200; David A. Aschauer, "Why Is Infrastructure Important?" in *Is There a Shortfall in Public Capital Investment?* Conference Series No. 34 (Boston: Federal Reserve Bank of Boston, June 1991); David A. Aschauer, "Is The Public Capital Stock Too Low?" *Chicago Fed Letter* (October 1987); David A. Aschauer, "Rx for Productivity: Build Infrastructure," *Chicago Fed Letter* (September 1988). Alicia H. Munnell reviews and extends Aschauer's work in "Why Has Productivity Growth Declined? Productivity and Public Investment," *New England Economic Review* (Boston: Federal Reserve Bank of Boston, January/February 1990), pp. 3-22.

Much of the uncertainty that surrounds studies using aggregate national statistics is unavoidable because of the limitations of available data. The data on public capital are sparse, available only on an annual basis and only for years since 1948. Moreover, the variables of interest (output, labor, private capital, and public capital) are all highly correlated, not only with one another but also with unrelated economic phenomena. Separating the effects of the observed variables from one another and from other unrelated but correlated variables is therefore difficult.

The ambiguity of statistical results based on aggregate time-series data is shown in Figures 2 and 3. Figure 2 shows the strength of the statistical association between private business output and net nonmilitary public capital stocks. When adjusted for time trends, private output per hour worked rose fairly steadily between 1950 and 1973, the date that many economists give as the beginning of the slowdown in the growth of U.S. productivity. After 1973, U.S. private business output fell relative to the trend. Evidence for the claim that low spending on public infrastructure was the principal cause of this decline lies in comparing the pattern of trend-adjusted output with the pattern of trend-adjusted stocks of public capital. Starting in 1950, net public capital stocks rose steadily until shortly before the downturn in trend-adjusted output. Similarly, the post-1973 decline in trend-adjusted output was accompanied by a steady decline in trend-adjusted public capital stocks. Statistical analysis captures this correlation between private output and public capital stocks, and shows that much of the change in private output can be "explained" by changes in net investments in infrastructure.

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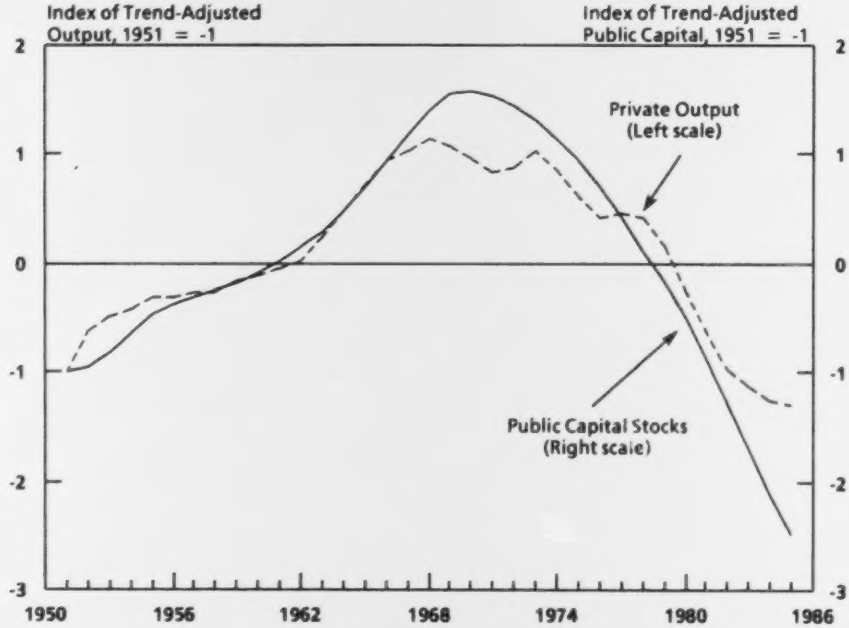
[12] The many evaluations of Aschauer's results include Henry J. Aaron, "Comments," in Munnell, ed., *Is There a Shortfall in Public Capital Investment?*; Charles R. Hulten, "Infrastructure: Productivity, Growth, and Competitiveness," Hearing Statement before the House Committee on Banking, Finance and Urban Affairs, Subcommittee on Policy Research and Insurance (May 8, 1990); Charles R. Hulten and Robert M. Schwab, "Is There Too Little Public Capital?" (paper presented at the American Enterprise Institute, Washington, D.C., February 1991); Dale W. Jorgenson, "Fragile Statistical Foundations: The Macroeconomics of Public Infrastructure Investment" (paper presented at the American Enterprise Institute, Washington, D.C., February 1991); Laura S. Rubin, "Productivity and the Public Capital Stock: Another Look," *Economic Activity Section Working Paper Series*, Number 118 (Washington, D.C.: Board of Governors of the Federal Reserve System, 1991); and John A. Tatom, "Public Capital and Private Sector Performance," *Review* (St. Louis, Mo.: Federal Reserve Bank of St. Louis, 1991).

The correlation between private output and public capital, however, may be coincidental, and the inference that changes in public capital caused changes in private output may be mistaken. The nature of the data calls for caution in using any statistical results. Since the changes in both private output and net infrastructure investments are smooth over time--rising fairly steadily during the first 20 years of the

Figure 2.
Relationship Between Private Output and Public Capital Stocks, 1951-1985

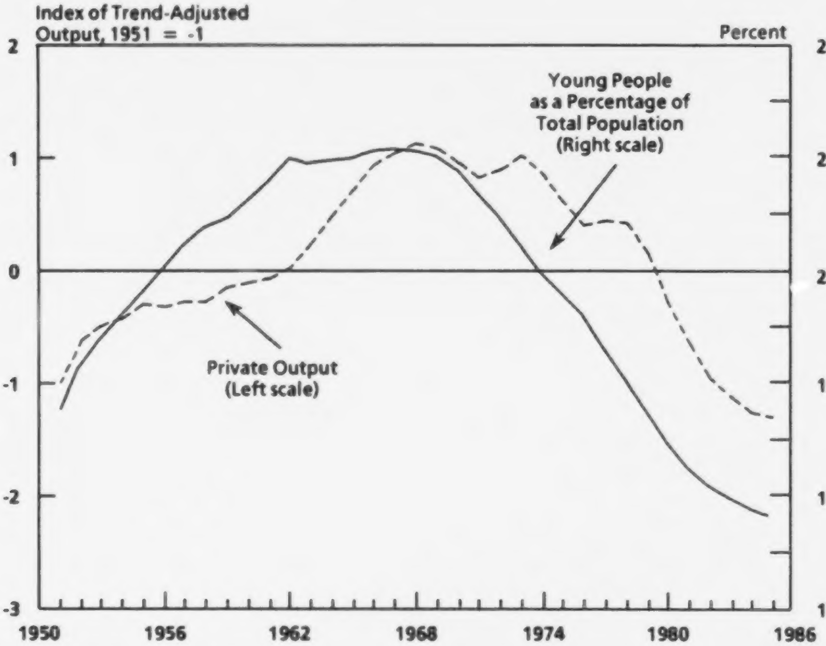


SOURCE: Congressional Budget Office using data from the Bureau of Labor Statistics and the Bureau of Economic Analysis.

NOTE: Private output is measured by a three-year moving average of private business output per hour worked (adjusted for time trends). Public capital stocks are measured by net nonmilitary public capital stocks (adjusted for time trends).

period and falling thereafter-- statistical analysis would show changes in private output as being "caused" by any data series that followed this same simple time profile. The ease with which a spurious relationship can be found is illustrated in Figure 3. That figure shows trend-adjusted private business output, but it also shows the number of young people (ages 5 to 15 years) as a percentage of the total population. This percentage follows the same smooth path as public capital stocks, rising through 1968 and falling thereafter. When this per-

Figure 3.
Relationship Between Private Output and Young People as a Percentage of the Total Population, 1951-1985



SOURCE: Congressional Budget Office using data from the Bureau of Labor Statistics; and *Economic Report of the President* (February 1991).

NOTE: Private output is measured by a three-year moving average of private business output per hour worked (adjusted for time trends). Young people are those between ages 5 and 15 years.

TABLE 2. THE MARGINAL PRODUCT OF PUBLIC CAPITAL RELATIVE TO PRIVATE CAPITAL, FOR DIFFERENT DATA SETS AND SAMPLE PERIODS

Bureau of Labor Statistics Data Set	1949-1985	1950-1985	1953-1985
Original Data on Private Business Output	3.4	4.8	4.7
Revised Data on Private Business Output	2.4	19.6	28.1
Revised Data on Nonfarm Business Output	6.4	10.5	27.7

SOURCES: Congressional Budget Office estimates based on data cited in David A. Aschauer, "Is Public Capital Productive?" *Journal of Monetary Economics*, vol. 23 (1989), pp. 177-200; and Bureau of Labor Statistics, "USDL News Release 88-478."

centage is used in statistical analysis in place of data on public capital, it appears to "explain" private output with as much statistical significance as does public capital. Yet there is little reason to expect that the relationship reflects anything more than coincidence. The association that Aschauer noted between private business output and stocks of public infrastructure may also be largely coincidental.[13]

Interpreting the statistical results is also made difficult by the sensitivity of these results to the data sources used and the sample period examined. Table 2 illustrates this sensitivity. Aschauer's work, for example, used Bureau of Labor Statistics (BLS) data on the private business economy and found public capital to be more than three times as productive as private capital. The BLS periodically revises those data. Reestimating Aschauer's equations with newer BLS data still shows public capital to be more than twice as productive as private capital.[14] When the farm sector is excluded, however, public capital appears to be more than six times as productive as private capital.

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13. The correlation between private business output and certain demographic characteristics is noted in Rubin, "Productivity and the Public Capital Stock." Apparently spurious correlations between private output and other variables are noted in Aaron, "Comments."

14. The original data are described in Aschauer, "Is Public Capital Productive?" The revised BLS data are shown in a BLS news release (USDL 88-478) dated September 30, 1988.

Table 2 shows that these estimates can change substantially with the historical period examined. Aschauer's original results are based on data for the period 1949 through 1985. Yet after dropping just a single observation, and looking at the period 1950 through 1985, the revised data yield estimates showing public capital to be not two but twenty times as productive as private capital.[15]

Taken literally, these estimates imply that investments in public capital would increase private economic output between two and twenty times as much as would investments in private plant and equipment. At the same time, some of the statistical results indicate that private capital has only a negligible influence on economic output. Together, these implausible results raise the possibility of a spurious correlation between private output and public capital: the correlation between output, public capital, and private capital may be so strong that statistical analysis cannot accurately determine the extent to which changes in private output are brought about by one form of capital or the other.

The empirical results are also sensitive to the manner in which public and private capital are measured. Aschauer's estimates include a measure that accounts for the intensity with which private capital is used. This "capacity utilization" measure is needed because output depends not only on the amount of capital available, but also on how intensely that capital is used. The intensity with which the capital stock is used varies with the business cycle: business responds to changes in demand for its output not only by using more or fewer machines, but also by using the machines it already has more or less intensively. The BLS measure of private capital services attempts to incorporate some of the differences in the use of capital over time.[16]

Aschauer's regressions follow the standard practice of using the Federal Reserve Board's capacity utilization index to adjust further for the use of private capital.[17] He makes no attempt, however, to account for variations in the intensity of the use of public capital. Yet changes in public capital use might best be measured separately. Hulten and Schwab note that capacity utilization for highways and roads, for example, differs substantially from that for private capital generally. The economies of scale in road construction made it economical to build highways during the 1960s in anticipation of future demand. Thus, total lane miles grew far more quickly than did the number of vehicle miles traveled between 1956 and 1968. Since then, the number of lane miles built has grown more slowly than traffic, and a greater proportion of total road capacity has been used. Adjusting the stock of roads to reflect actual use leads to implausible statistical results: when a measure of congestion is included, statistical analysis shows that the economic benefits from additional roads are greater when existing roads are *not congested* than when they are congested.[18]

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[15] Similar results obtain when the sample period begins any time between 1950 and 1954. Moreover, the revised data need to be adjusted for serial correlation, but the original data do not. Many of the works cited in footnote 13 explore further the extent to which such results vary with the statistical techniques used.

[16] See Department of Labor, Bureau of Labor Statistics, *Trends in Multifactor Productivity, 1948-81*, Bulletin 2178 (September 1983), pp. 27-28.

Using production-function studies to examine the contribution of individual types of public capital to economic output yields estimates that are similarly unreliable. Public capital spending encompasses a diverse group of investments. Some of these investments (such as highways and airports) should influence private economic activity more directly than others (such as park facilities and public auditoriums). Statistical results that show that private economic activity is being influenced more by infrastructure such as highways and airports than by other forms of public capital would support the estimates of the relationship between private economic output and aggregate public capital. Aschauer presents just such results: his estimates suggest that private output would increase more than twice as much in response to added core infrastructure as it would in response to additions of other forms of public capital.[19] Moreover, nearly 75 percent of public capital's effect on output is attributable to changes in stocks of core infrastructure. Work with state-level data also finds evidence that only core infrastructure affects private output.

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[17] The virtues and limitations of different measures of capacity utilization are reviewed in Frank de Leeuw, and others, *Measures of Capacity Utilization: Problems and Tasks* (Washington, D.C.: Board of Governors of the Federal Reserve System, July 1979); and Matthew D. Shapiro, "Capital Utilization and Capital Accumulation: Theory and Evidence," *Journal of Applied Econometrics* vol.1 (1986), pp. 211-234.

[18] See Hulten and Schwab, "Is There Too Little Public Capital?"

[19] See Aschauer, "Is Public Capital Productive?" pp. 193-194; and Aschauer, "Is the Public Capital Stock Too Low?" and "Rx for Productivity." Aschauer defines "core infrastructure" as including

(Continued)

A variety of statistical evidence, however, illustrates the uncertainty of these results. The most striking evidence follows from the recently revised BLS data on the private business economy. Recalculating Aschauer's estimates using the revised data completely reverses the estimation results: an added dollar of core infrastructure is estimated to increase private output only one-half as much as would another dollar of other public capital. Even the older BLS data, however, can support equally any number of claims about the importance of different types of public capital. The older data show, for example, that hospital buildings and conservation facilities (dams) together have a marginal product more than twice that of all other capital, including core infrastructure. In the end, neither the new data nor the old are able to establish the relative importance of different public capital investments in any statistically meaningful fashion.

Unfortunately, no statistical basis exists for choosing between those estimates indicating that public capital (of various types) has large effects on private output and those showing that it has none. Instead, the reasonableness of these differing estimation results must be inferred from other, related statistical studies. Among the relevant studies are those that look at the effect of public capital on private output across regions or countries.

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19. Continued

four of the nine categories in the Bureau of Economic Analysis's public capital data: highways, sewers, water supply, and other structures (including airports, aviation, transit systems, and electric and gas utilities). The five "noncore" public capital categories include education buildings, hospital buildings, other public buildings (such as office buildings, police and fire stations, courthouses, and auditoriums), conservation and development structures (such as dams and park facilities), and federal industrial buildings. Research using state-level data is reported in Alicia H. Munnell, "How Does Public Infrastructure Affect Regional Economic Performance?" in Munnell, ed., *Is There a Shortfall in Public Capital Investment?*

Studies with Regional Data

Recognizing the problems caused by limited national-level data, researchers have turned to the more broad-based data available for regional and international comparisons. One recent study, using state-level data for the period 1970 through 1986, found strong evidence that state and local public capital influences gross state product, and more limited evidence that the marginal product of public capital may be as large as the marginal product of private capital.[20] The latter conclusion is itself noteworthy, given that much public investment is designed to further social goals rather than simply to promote economic growth.

Other regional studies suggest a more limited role for public capital in economic growth. One study examined regional differences in productivity growth in the manufacturing sector during the 1951-1978 period.[21] Because the study included measures of private capital and labor but not public capital, it offers only an indirect test of public capital's role in explaining growth in productivity. The study found, however, that changes in private inputs explain nearly all of the variation in regional productivity growth, leaving little room for the effect of public capital.

Another study examined the growth in manufacturing productivity in 40 metropolitan areas between 1965 and 1977.[22] By constructing data series showing both public and private capital stocks in these areas, the study was able to test directly the role of public capital in regional differences in productivity growth. The effect of public capital on private manufacturing output was found to be limited. As in the earlier, indirect test, changes in manufacturing output were best explained by changes in private input levels; public capital's influence was found to be not statistically different from zero. What influence public capital does have on private output seems to arise from its influence on decisions about where to locate private inputs: public capital appears to provide amenities that make individual regions more attractive to labor and capital, and it is these movements in private inputs that influence output. Public capital appears to have no influence on private output independent of its effect on the geographic distribution of private inputs.

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[20] Munnell, "How Does Public Infrastructure Affect Regional Economic Performance?"

[21] See Charles R. Hulten and Robert M. Schwab, "Regional Productivity Growth in U.S. Manufacturing: 1951-1978," *American Economic Review*, vol. 74, no. 1 (March 1984). These results have been updated and extended in Hulten and Schwab, "Public Capital Formation and the Growth of Regional Manufacturing Industries," Department of Economics, University of Maryland (mimeo, March 1991).

[22] Randall W. Eberts, "Cross-Sectional Analysis of Public Infrastructure and Regional Productivity Growth," Federal Reserve Bank of Cleveland, Working Paper No. 9004 (May 1990).

Studies with International Data

International data present a mixed picture of the relation between public capital and economic growth. Aschauer looks at data for the "Group of Seven" industrial countries for the 1966-1985 period and finds that labor productivity responds positively to increases in the ratio of public nonmilitary net investment to gross domestic product.[23] With data from 98 industrial and developing countries for the period 1960 to 1985, however, Barro finds that public investment has little relation with growth. By itself, the ratio of government investment to gross domestic product has no statistically significant influence on economic growth. Barro's findings indicate that the impact of public investment on private economic output is, at best, no greater than that of private investment.[24] A third work suggests that the very different conclusions of Barro and Aschauer should be expected: Tanzi finds that the inclusion or exclusion of data for a single country can determine whether public capital has any statistically significant influence at all on private output.[25]

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23. David A. Aschauer, "Public Investment and Productivity Growth in the Group of Seven," *Economic Perspectives* (Chicago: Federal Reserve Bank of Chicago, September/October 1989). The Group of Seven countries include the United States, Japan, West Germany, France, the United Kingdom, Italy, and Canada.

24. Robert Barro, *Economic Growth in a Cross Section of Countries* (Cambridge, Mass.: National Bureau of Economic Research, Inc., September 1989).

25. Vito Tanzi, "The IMF and Tax Reform," IMF Working Paper (April 1990), cited in Henry J. Aaron, "Comments."

The Direction of Causality

Finally, all of these studies leave unresolved the question of whether public capital influences economic output or the other way around. It is possible that the strong correlation between private productivity growth and public capital investment reflects the influence of public capital on productivity and output. Most authors note, however, that the correlation instead might reflect the effect of productivity growth on public investment. The slowdown in productivity growth, by lowering growth in income, might have reduced the amount of public investment desired, because a large part of the benefits from infrastructure accrue not to businesses but to individuals. Individuals might well be expected to respond to lower growth in income by purchasing less infrastructure. This hypothesis has been tested most directly on data from 40 metropolitan areas for the period 1904 to 1978 using statistical tests designed to determine the direction of causation.[26] The data provide no clear indication about the direction of causality: changes in public capital investment "caused" changes in private investment in about 40 percent of the metropolitan areas examined; the causality appeared to be reversed in another 40 percent of the metropolitan areas; in the remaining metropolitan areas, causality was indeterminate.[27]

Overall, macroeconomic studies allow one to draw only the broadest conclusions about the relation between public investment and economic growth. Many studies find that public capital does influence private economic output. With a few notable exceptions, however, these studies suggest that private economic output could be increased more efficiently through additions to private capital than through additions to public capital.

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[26] See Randall W. Eberts and Michael S. Fogarty, "Estimating the Relationship Between Local Public and Private Investment," Federal Reserve Bank of Cleveland, Working Paper No. 8703 (May 1987).

[27] "Causation" is determined here in the best fashion that statistics can muster: public investment is assumed to "cause" private investment if changes in public investment can predict changes in private investment more accurately than changes in private investment can predict themselves.

THE ECONOMIC RETURN ON FEDERAL INFRASTRUCTURE INVESTMENT: EVIDENCE FROM COST-BENEFIT STUDIES

The returns to investments in public infrastructure can also be measured by estimating the costs and benefits of individual projects or types of projects. By focusing on narrower groups of investments, such cost-benefit studies can take into account the importance of particular circumstances in determining whether certain additional investments will be beneficial. In particular, such studies yield estimates of the rate of return to additional public investments. If the rate exceeds that available on additional private investments, increased federal spending in this area is likely to expand output.

Despite their practicability, however, few cost-benefit analyses have been conducted for different infrastructure investment strategies. The limited available evidence shows that returns to public investment vary widely for different types of infrastructure, for different regions, and between new construction and maintenance of existing assets. In selected instances, however, the evidence suggests that additional spending would expand private output.

Investments in Aviation

Cost-benefit evidence on aviation spending suggests that increased public capital outlays for airport capacity could yield substantial returns and expand output. The deregulation of the airline industry beginning in 1978 led to a rapid rise in air travel. Federal Aviation Administration forecasts indicate that the demand for air travel will continue to rise rapidly through the end of the century.[28] The rise in travel, together with the development of a hub-and-spoke system of airports, has led to growing delays both at airports, largely the province of state and local authorities, and in airways, for which the federal government retains sole responsibility. The FAA has estimated that costs of delay for passengers and additional operating costs for carriers approach $5 billion annually.

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[28] Federal Aviation Administration, *FAA Aviation Forecasts: Fiscal Years 1990-2000* (March 1990).

The two principal sources of delay in the aviation system are insufficient capacity for air traffic control in some areas and an inadequate amount of runway and terminal space at some airports. Cost-benefit studies suggest that investments made to expand the capacity of the aviation system would have relatively high rates of return. In the early 1980s, the Federal Aviation Administration completed plans for modernizing the airspace system.[29] The initial research and development phase of those plans is nearly completed. The Administration's budget proposes to continue the modernization of the national airspace system through a 29 percent increase in funding for FAA facilities from approximately $2.1 billion in 1991 to $2.7 billion in 1992. There is little evidence to help predict the economic returns from these outlays. The last thorough cost-benefit study of FAA's modernization plan, completed in 1983, found that the plan represented a sound economic investment.[30] Since the time of that study, congestion has worsened and the FAA's air traffic control equipment has aged, suggesting that the returns to the current plan would be at least as great as estimated eight years ago.

Another major cause of aviation congestion lies with the airports themselves. The expansion of runways, taxiways, landing aids, and terminals could reduce congestion at those airports with sufficient control capacity to accommodate increased ground and air traffic. The benefits from added airport capacity may be substantial. Current annual aviation investments by all levels of government total approximately $4.0 billion. One recent cost-benefit study estimated that building additional runway capacity with an annualized cost of $1.5 billion would yield annual benefits of $11 billion for several years--clearly suggesting a high rate of return. Nearly all of the benefits would take the form of reduced waiting time for passengers ($7.9 billion) and lower operating costs for carriers ($2.8 billion).[31]

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[29] See Department of Transportation, *National Transportation Strategic Planning Study* (March 1990), Chapter 11.

[30] See Congressional Budget Office, *Improving the Air Traffic Control System: An Assessment of the National Airspace System Plan* (August 1983).

[31] The $1.5 billion figure represents the amount that runway investment would increase if airport pricing and investment met the criteria for economic efficiency. See Clifford Winston, "Efficient Transportation Infrastructure Policy," *The Journal of Economic Perspectives* (Winter 1991). Data on current spending are CBO estimates.

This estimate, however, understates the costs of capacity improvements and overstates the benefits to be gained from them. It understates costs by omitting the expenses of acquiring land and compensating individuals for noise from increased air traffic. The estimate overstates benefits by assuming that airports will introduce more efficient prices for their services at the same time that they expand their capacity. (Assuming that airport services are priced efficiently is equivalent to assuming that new airport capacity is made available first to those who value it the most.) Recognizing this problem, the study also presents the amount that users of individual airports would be willing to pay each year for the capacity provided by an additional runway. Under current policies, these benefits would range from $5.5 million per year at San Antonio International Airport to $583.3 million per year at New York's La Guardia Airport, as shown below:[32]

Airport	Benefits (Millions of 1988 dollars)
New York (LaGuardia)	583.3
Chicago (O'Hare)	138.1
Washington (National)	91.7
Denver (Stapleton)	75.6
San Antonio (International)	5.5

A significant fraction of the benefits from greater runway capacity could be achieved by using existing capacity more efficiently. Price incentives could help make better use of limited capacity. Airlines, for example, might be charged a landing fee that did not vary with airplane size, or charged more for taking off and landing during peak periods. Current airport landing fees are based primarily on aircraft weight. The congestion caused by landings and takeoffs, however, varies little with aircraft size. Current landing fees thus provide incentives against using aircraft that would reduce congestion by carrying the greatest number of people per landing. At the same time, landing fees rarely vary by time of day, although airport congestion is highly concentrated in peak periods. Varying airport landing fees by time of day would shift some traffic to off-peak hours. One study has estimated that efficient airport pricing alone would provide net benefits of $3.8 billion annually.[33]

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[32] See Steven A. Morrison and Clifford Winston, "Enhancing the Performance of the Deregulated Air Transportation System," *Brookings Papers on Economic Activity: Microeconomics 1989* (Washington, D.C.: Brookings Institution, 1989), pp. 86 and 96-99. For a discussion of technological changes that could increase airport capacity without substantial investment, see Transportation Research Board, *Airport System Capacity: Strategic Choices*, Special Report 226 (Washington, D.C.: TRB, National Research Council, 1990).

Investments in Highways

Cost-benefit analysis also finds substantial returns to some increases in federal spending for highways, which accounts for about 55 percent of all federal investments in physical infrastructure. In a 1987 report, the Federal Highway Administration examined the benefits and costs of various incremental spending strategies, ranging from a continuation of current spending to a program of fixing all deficiencies. Further evidence is available from a 1988 CBO report that estimated rates of return of selected highway construction projects. The resulting estimates, shown in Table 3, may have substantial margins of error; they are intended to illustrate the relative rates of return on different types of investment rather than provide precise estimates of the level of rates of return on highway investments generally.[34]

The estimates from these studies indicate that carefully selected highway projects would yield high rates of return (see Table 3). In general, rates of return would be far higher on maintenance spending than on projects to expand capacity. The first strategy examined in the 1987 study--increasing highway spending enough to maintain current road conditions--would have yielded a rate of return between 30 percent and 40 percent. Similarly, selected projects to add new capacity in congested urban areas would have generated returns between 10 percent and 20 percent. Further increases in highway spending, however, would have yielded far lower rates of return. Bringing all road sections up to minimum standards of service or safety, for example, would have generated a rate of return between 3 percent and 7 percent. And fixing all those highway deficiencies above minimum standards of service and safety would have generated a negative rate of return.

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[33] See Morrison and Winston, "Enhancing the Performance of the Deregulated Air Transportation System."

[34] See Congressional Budget Office, *New Directions*, Chapter I; and Report of the Secretary of Transportation to the Congress, *The Status of the Nation's Highways: Conditions and Performance*, Committee Print 100-11 (June 1987).

Two caveats accompany these estimates. First, the results may understate the cost of construction in urbanized areas, for they ignore the cost of purchasing land and the cost of noise and air pollution in developed urban areas. Second, the results understate benefits by assuming that improvements are made to respond to design standards rather than to optimize costs and benefits.

As with airport investment, much of the benefit from added highway investments could be achieved simply by using existing assets more efficiently. The taxes that each highway user currently pays bear little relation to the damage to the pavement that he or she causes. Damage to pavement results principally from the weight of the vehicle (measured as weight per axle). Damage rises so quickly with weight per axle that almost all of it results from the passage of heavy trucks rather than passenger vehicles. Current highway taxes, however, provide no incentive to optimize vehicle weight per axle. Replacing current highway taxes with fees based on vehicle weight per axle

TABLE 3. ECONOMIC PRIORITIES FOR HIGHWAY INVESTMENT

Investment Strategy	Expected Real Rate of Return on Investment (National averages)
Maintain Current Highway Conditions	30 percent to 40 percent
Selected New Construction, Urban Areas	10 percent to 20 percent
Upgrade Sections Not Meeting Minimum Service or Safety Standards	3 percent to 7 percent
Fix All Deficiencies Above Minimum Service and Safety Standards	Negative

SOURCE: Congressional Budget Office based on data from the Federal Highway Administration.

and distance driven could, over time, lead to the use of trucks that would impose far less damage on roads. One study estimated that optimal taxation of road damage would yield annual net benefits of more than $5.4 billion.[35]

Other Types of Investments in Physical Infrastructure

Far less analysis has been done for spending on other types of infrastructure, but the available evidence suggests that spending on maintenance would usually generate a higher rate of return than spending on capacity-enhancing projects. Water resources offer the clearest picture of this situation. The Bureau of Reclamation--the federal agency charged with the lead role in developing Western water resources--recently concluded that the era of building major dams had ended. In most cases, agricultural, municipal, and industrial water supplies could be provided more economically through better management of existing resources. The situation is similar with inland waterways. Large investments may be needed in coming decades to replace aging locks and dams on some waterways. Yet a Department of Transportation study concluded that requiring shippers merely to pay the cost of operating and maintaining existing locks and dams would render 4 out of 12 waterway segments commercially inviable.[36] One might therefore expect new capacity-enhancing projects to offer adequate rates of return only in the few high-traffic corridors.

Taken as a whole, cost-benefit analysis paints a fairly consistent picture of high returns to maintaining the existing stock of physical infrastructure and to expanding capacity in some areas, such as congested urban highways and runway capacity and air traffic control at major airports. Cost-benefit studies also show substantial benefits from using existing infrastructure more efficiently. Cost-benefit analysis offers little evidence, however, that substantial across-the-board increases in current public capital programs would have a marked effect on economic output.

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35. See Winston, "Efficient Transportation Infrastructure Policy." This study also examines the effects of imposing taxes to reduce road congestion.

36. Department of Transportation, *Inland Waterway Taxes and Charges* (1982).

CONCLUSION

Most empirical studies show that public infrastructure investments can improve private economic performance. Yet the importance of public infrastructure remains uncertain. The evidence does not support claims that private economic output would be better enhanced by broad-based increases in public infrastructure spending than by greater investments in private capital. Empirical studies instead show that returns to public investments vary widely. The most careful empirical research has been done for investments in highways and aviation. Those studies indicate that returns are highest for maintaining existing assets and for expanding capacity at certain congested facilities. Substantial economic benefits also could be achieved through more efficient use of existing infrastructure assets, particularly highway and aviation facilities.

CHAPTER III

FEDERAL SPENDING ON HUMAN RESOURCE PROGRAMS AND ECONOMIC GROWTH

Gross national product can be increased by investments in human capital, as well as in physical capital. These investments differ from those discussed in the last chapter in that they are embodied in people. Any economic payoffs from the investments will show up as improvements in people's subsequent earnings and well-being. Parents and teachers invest in human capital by nurturing children. Students invest in themselves through time spent studying, rather than playing or working. These are everyday examples of investments in human capital.

Investing in human capital may offer benefits that are not reflected in economic measures. To a greater extent than is the case with investments in physical capital, programs to expand human capital are intended to lead to improvements in well-being, such as better health, reduced crime, or reduced federal outlays for welfare programs.

The federal government actively develops human capital through programs intended both to increase the productive capacity of the U.S. population and to improve their welfare in other ways. For example, federal funding of education programs may result in a labor force better prepared to handle the complex tasks of the modern workplace. Programs that improve children's physical and mental development may enable them to be more productive later in life.

This chapter addresses two issues:

- How much of the federal budget is spent on investments in human capital?
- What are the returns from these investments?

Since there is no definite criterion for separating those federal programs that should be considered investments in human resources from those that should not, this chapter develops three successively broader categories of such programs. The narrowest category includes only programs for education and training, the second adds social service programs, and the last one adds programs of nutritional assistance. Health programs are discussed, but are not treated formally as investments in human resources.

Evaluating the effectiveness of human resource programs is a particularly difficult process when using either the production-function approach or the cost-benefit method. One reason is that these programs have always been relatively small in proportion to the economy as a whole. Another is that the programs are designed to yield nonmarketed benefits that are difficult to measure or to compare with economic returns.

Still, many programs in the narrowest category have increased the earnings of their participants. In some cases, including a work-related project for welfare recipients examined in this chapter, increases in participants' earnings have exceeded the programs' costs sufficiently to suggest that such expenditures can be considered good investments. Programs in social services and nutritional assistance, for their part, are most often aimed at such goals as reducing welfare caseloads, increasing health, and cutting crime. Many programs have been found to be effective in achieving these noneconomic (or not directly economic) purposes.

After presenting the analytic framework for considering certain activities as investments in human capital, this chapter surveys the major federal investment programs and examines the extent to which such programs promote the nation's economic goals, as well as other objectives. Evaluations of the Job Corps and of recent work-related programs for welfare recipients are used to illustrate how human resource investments may be assessed.

HUMAN CAPITAL

The term human capital has been defined as "the stock of skills and productive knowledge embodied in people."[1] Students of the economy at least as far back as Adam Smith have observed the contribution of improved job skills to economic output and to the workers' own earnings. Later economists have broadened the concept of investment in human capital to include activities that improve health and longevity, as well as traditional education, formal training, and informal acquisition of skills through work experience.

The Idea of Human Capital

As with other investments, rates of return on investments in human capital can be determined, in principle, by comparing the costs of the investment with the expected stream of benefits that would result. In the case of an investment in another year of education, for example, the costs include the sacrifice of other uses of the student's time, as well as the direct costs of the educational services provided. The returns include the expected increase in the value of the goods and services that the student would produce as a result of the additional education.

A fundamental difference between human capital and physical capital is that the former is generally embodied in a person and cannot be sold. It is more difficult to obtain private financing for human investment than for physical investment because the former does not result in collateral--capital that the lender can acquire in the event of default. As discussed below, this difference provides one of the rationales for government involvement.

The notion that resources expended for training and other activities that yield returns in the future are more like investments in machinery than like current consumption became the basis for an outpouring of research starting in the late 1950s.[2] Numerous researchers have used the concept in analyzing sources both of economic growth and of disparities in earnings between people with different amounts of education and experience.

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[1] The next three paragraphs draw heavily on Sherwin Rosen's entry on "human capital" in *The New Palgrave: A Dictionary of Economics*, edited by J. Eatwell and others, vol. 2 (New York: Stockton Press, 1987), pp. 681-690. The quoted phrase is on p. 682.

The idea, though simple, is controversial. Many educators, for example, do not like to think of what they are doing as akin to building machinery or roads, nor do they agree that success or failure of their endeavors may be properly measured by their effect on the future earnings of their students. Many analysts would argue that much of the time students spend in school is current consumption, not investment, and that the main effect on their future well-being is to make them more cultured human beings, not necessarily more productive workers.

The Federal Role

Notwithstanding the tremendous growth in federal programs in the 1960s, the federal government's role in the formation of human capital--at least in terms of paying for the investments--remains an auxiliary one. State and local governments, not the federal government, sponsor most public education. Employers pay for much of the on-the-job training of their employees. The people within whom the capital is embodied, or their families, pay much of the cost of education and training, either in direct payments such as tuition and fees or in forgone earnings.

Government investments in human resources traditionally are supported on the grounds that they result in higher total output for the nation (efficiency) or that the output is distributed more fairly (equity). The efficiency basis is akin to the conventional argument for government support of other forms of infrastructure. These arguments were discussed in detail in Chapter I and need only a brief discussion here. The equity basis has a stronger link to investments in human resources than to physical investments and, therefore, is examined more closely.

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[2] Gary Becker, Jacob Mincer, and others developed and applied this concept extensively in these years. Adam Smith, in 1776, stated the analogy between investment in physical capital and investment in human capital: "When any expensive machine is erected, the extraordinary work to be performed by it before it is worn out, it must be expected, will replace the capital laid out upon it, with at least the ordinary profits. A man educated at the expense of much labor and time to any of those employments which require extraordinary dexterity and skill, may be compared to one of these expensive machines." See Adam Smith, *The Wealth of Nations* (London: J.M. Dent and Sons, Ltd., 1977), p. 90.

Efficiency and Economic Growth. The basic efficiency rationale for government involvement is that markets otherwise will fail in the sense that, without government intervention, the level of investment in human resources will be less than what is needed for optimal economic production. For example, employers will invest less in the skills of their workers than would be beneficial to society as a whole because they cannot be sure that the employees will remain with them long enough to warrant the investment. Similarly, individuals will not invest enough in their education to maximize the economy's production because many lack sufficient income and assets and cannot borrow by using their human capital as collateral. Because businesses and individuals may not invest enough from the economy's point of view, it is up to government to do so. Only investments that appear productive on the basis of analyses using the production-function or cost-benefit approaches, however, should be undertaken based on the efficiency rationale.

The payoff to society as a whole from subsidizing investments in human resources may go well beyond effects on the economy. Reduced crime, better informed consumers and voters, and improved rearing of the generation that follows are but a few of the benefits that have been claimed. Investments that offer noneconomic payoffs like these are classified under the efficiency approach even though they may not expand the measured output of the economy. The effectiveness of these investments in promoting other purposes should also be tested using the cost-benefit approach. In many cases, however, measuring nonmarketed costs and benefits adequately proves difficult.

Equity. Although some federal involvement came about because of an interest in promoting economic growth (for example, the initial support for vocational education), most federal funding probably resulted from a view that state and local governments were not investing sufficient resources in people with low income--more a concern about equity than about efficiency. Most of the federal education and training programs that were started in the 1960s, in particular, sought to reduce inequalities in opportunities that state and local governments were seemingly unable or unwilling to address, or were addressing to different degrees.

Concerns about the distribution of opportunities led to enactment of legislation that directed federal funds for education and other human resource programs to states and localities that had disproportionate numbers of people with low incomes. Apportionment formulas for elementary and secondary education and for job training programs, for example, reflect this approach. These concerns also led to the use of program eligibility criteria to funnel federal resources to people with low incomes or other disadvantages. Financial assistance for higher education is based, in part, on this approach.

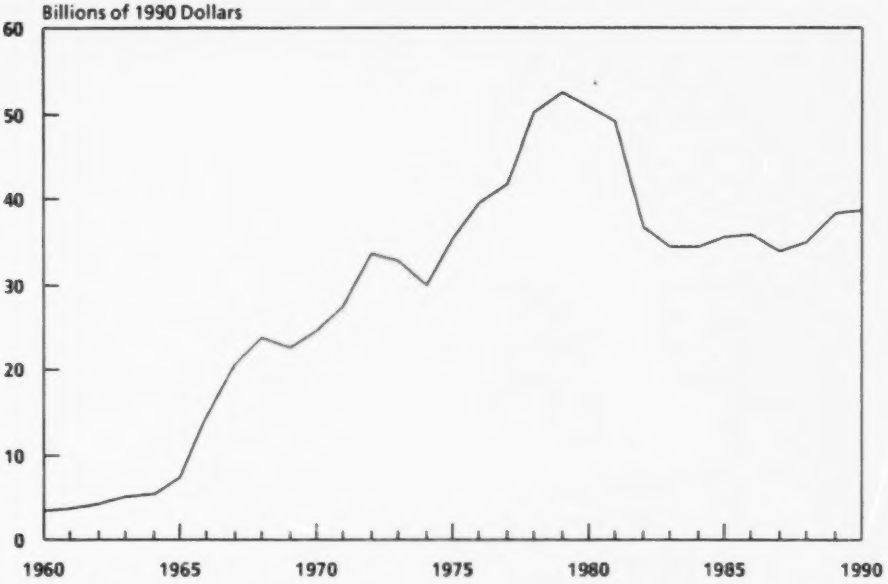
FEDERAL INVESTMENT IN HUMAN CAPITAL

Federal involvement in the growth of the stock of human capital can be traced back at least as far as the establishment of land-grant colleges by the Morrill Act of 1862, but did not take on its current form for another century. Particularly since the 1960s, the federal government has played a prominent part in funding education, training, and other human resource activities.

The Growth of Federal Spending on Human Resource Programs

Most federal expenditures that might be classified as investments in human capital are found within the parts of the budget covering domestic spending for human resources, particularly the portion funding education, training, employment, and social services (budget function 500). Between 80 percent and 97 percent of the estimated outlays for human capital investment in 1990 under the alternative criteria presented below are in budget function 500. With the formation of the Great Society programs in the mid-1960s, expenditures on programs in this function have grown enormously. Among the numerous additions

Figure 4.
Federal Outlays for Education, Training, Employment, and Social Services, Fiscal Years 1960-1990



SOURCE: Congressional Budget Office.

to the language of educators and trainers were the Job Corps (1964), Head Start (1965), the Elementary and Secondary Education Act (1965), and the Higher Education Act (1965).

Expenditures for education, training, employment, and social services mushroomed from about $3 billion in 1960 to $24 billion in 1968 and to $34 billion in 1972, as depicted in Figure 4. (These and all other amounts in this section are presented in 1990 dollars.) After still further growth throughout most of the 1970s, total outlays peaked at $52 billion in 1979 and have since fallen back to roughly $38 billion.[3] As a percentage of the nation's total output, federal expenditures for these programs increased from 0.2 percent of GNP in 1960 to 1.2 percent of GNP in 1979, and have since declined to about 0.7 percent in 1990.

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[3] The peak in 1979 included about $9 billion for public service employment programs authorized by the Comprehensive Employment and Training Act (CETA), which were largely for creating temporary jobs rather than for developing human capital.

Delineating the Scope of the Investment

How large is the federal investment in human capital? Analysts cannot agree on which federal activities should be counted as human capital investments; the issue may be inherently unresolvable. This section uses alternative criteria to estimate how much of the federal government's expenditures on human resource activities in 1990 could be counted as investments.

Distinguishing between federal expenditures that are investments in human capital and those made for other purposes necessarily involves making many judgment calls. If one could rank federal human resource programs according to whether they are primarily investments, rather than current consumption, training programs would probably be at the top of the list, most education programs and some social service and nutrition programs would follow, and most health expenditures would be near the bottom.

Moreover, even the payoff from programs intended primarily to improve workers' job prospects includes other important effects. Not taking these benefits into account would understate the worth of such programs both absolutely and relative to other investments whose returns are solely economic. For example, as discussed below, a substantial portion of the benefits to society estimated for the Job Corps derives from its success in reducing serious crime committed by its participants during and after their participation.

Using three alternative criteria, the estimated outlays for human resource programs that could be considered investments range from about $26 billion to $42 billion in 1990 (see Table 4). The narrowest criterion counts only programs for education or training. The next adds most programs that fund social services because they too help individuals to develop. The broadest (which goes beyond the programs included in function 500) also includes certain food and nutrition assistance programs, on the basis that they help the recipients lead more productive lives. (Tax expenditures for investments in human capital--such as the deductibility of charitable contributions for education--are relatively small and are not included in this analysis.)

The Narrowest Category: Education and Training Programs. The narrowest rule restricts what is counted as an investment to federal expenditures for education and training, applying a criterion also used by the Office of Management and Budget (OMB): programs whose primary purpose is to "add to the stock of human capital by developing a more skilled and productive labor force."[4] These activities (as shown in Table 4) include most of the education, training, and employment programs included in function 500 of the budget, as well as certain education and training programs for veterans, health care workers, and welfare recipients included in other budget functions.

Elementary, Secondary, and Vocational Education. Federal investments for elementary and secondary education are provided mainly for compensatory education, education for the handicapped, and vocational and adult education. The largest of these programs is the compensatory education program authorized by the Elementary and Secondary Education Act of 1965. Grants are provided to school districts for supplementary services to educationally deprived students.[5] Grants authorized by the Individuals with Disabilities Education Act provide states with funds for special education and related services to handicapped children.

Under the Carl D. Perkins Vocational and Applied Technology Education Act, states receive formula grants to help fund their vocational education programs in secondary and postsecondary schools. The funds are to be used to improve the programs and to provide equal opportunity for groups that had been underserved. Under the Adult Education Act, states are provided with grants to improve educational opportunities for adults.

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[4] "Special Analysis D," *Special Analyses, Budget of the United States Government, Fiscal Year 1990*, p. D-4.

[5] The objectives of the programs described in this chapter are largely as given in *1990 Catalog of Federal Domestic Assistance* (Washington, D.C., June 1990); and in *Budget of the United States Government, Fiscal Year 1992*.

Postsecondary Education. Pell grants account for the largest share of federal grants to postsecondary students. These grants are based on financial need, using a formula that takes into account individual and parental resources and the cost of the education. Federal assistance for campus-based aid is provided through grants to institutions for work-

TABLE 4. ALTERNATIVE ESTIMATES OF FEDERAL INVESTMENT IN HUMAN CAPITAL, 1990 (In billions of dollars)

Program	Outlays for Human Capital Investment
Narrowest Category: Education and Training	
Elementary, Secondary, Vocational Education	
Compensatory education	4.5
Education for the handicapped	1.6
Vocational and adult education	1.3
Other elementary, secondary[a]	1.7
Postsecondary Education	
Pell, other student financial assistance	5.9
Stafford, other guaranteed student loans	4.4
Other higher education[b]	0.8
Training, Employment Services	
Job Training Partnership Act (JTPA), other training funded through the Department of Labor	3.9
Employment service	1.1
Education and training of health workers	0.6
Job Opportunities and Basic Skills (JOBS) training program	0.3
Veterans' education, training, rehabilitation	0.3
Total, Education and Training	26.4

(Continued

SOURCE: Congressional Budget Office based on estimated outlays for 1990 reported in *Budget of the United States Government, Fiscal Year 1992*, Table A-2, and in related materials.

NOTE: The narrowest category limits what is counted as human capital investments to programs intended to develop a more skilled and productive labor force. The second category broadens the scope to include activities that help individuals develop, even though the major purpose of these activities might not relate to productivity in the labor market. The broadest category further expands the scope to encompass certain food and nutrition assistance programs provided mainly for children, on the basis that these programs help the recipients lead more productive lives.

study programs, supplemental education opportunity grants, and low-interest, long-term loans (Perkins loans).

Federally guaranteed loans to students (or their parents) are designed to help them meet the costs of attending postsecondary educational institutions. Under the largest of the loan programs--known as

TABLE 4. Continued

Program	Outlays for Human Capital Investment
Second Category: Education and Training, Social Services	
Education and Training	26.4
Social Services	
Head Start, other development[c]	2.6
Rehabilitation services	1.8
Foster care and adoption	1.6
Social services block grant	2.7
Subtotal, Social Services	8.7
Total, Education and Training, Social Services	35.1
Broadest Category: Education and Training, Social Services, and Food and Nutrition Assistance	
Education and Training	26.4
Social Services	8.7
Food and Nutrition Assistance	
Women, infants, and children (WIC)	2.1
School Lunch, other child nutrition[d]	5.0
Subtotal, Food and Nutrition Assistance	7.1
Total Investment	42.2

a. Primarily grants to states and local educational agencies for school improvement programs.

b. Includes aid for institutional development and special programs for disadvantaged students.

c. In addition to Head Start, includes expenditures on child welfare services and other child and family services.

d. Primarily for School Breakfast, summer food service, and child and adult care food programs.

Stafford loans--students may borrow at highly subsidized rates. Smaller, less subsidized programs include Parent Loans for Undergraduate Students and Supplemental Loans for Students.

Training and Employment Services. The Job Training Partnership Act largely provides job training and related assistance to economically disadvantaged individuals through grants to state and local authorities. In addition, the act authorizes the Job Corps--a residential training program for disadvantaged youth, discussed later in this chapter--and a summer youth employment and training program. Another part of the act provides funding for job training and related assistance to workers who have been displaced from their jobs. Other training and employment services for displaced workers are provided by the Trade Adjustment Act. Funds for the federal/state employment service support the operations of offices that provide no-fee employment services to job seekers and employers.

The federal government also helps fund a variety of training activities that are included in other parts of the budget. Three sets of activities whose objectives clearly include the development of a more skilled and productive labor force are counted as investments in Table 4. First, various health programs support the education and training of health care workers. These programs include subsidies for training biomedical and behavioral scientists, as well as physicians and other health care providers. Second, the Family Support Act of 1988 authorizes a major expansion of education, training, job search assistance, and work experience programs for recipients of Aid to Families with Dependent Children (AFDC). The new program--Job Opportunities and Basic Skills (JOBS)--is discussed below. Third, the Montgomery GI Bill provides financial assistance to veterans who enroll in postsecondary educational institutions.

Other Education and Training Programs. A few items in the education, training, and employment part of the budget are not counted as investments in human capital because they do not appear to meet the narrow criterion of adding to the stock of human capital. The School Assistance in Federally Affected Areas program (also known as Impact Aid) is excluded because it is mainly intended to compensate school districts that have children whose parents live or work on federally owned property. (One could argue for its inclusion, however, on the basis that the program probably increases total spending for education.) The category "research and general education aids" is excluded because the majority of the spending in this subfunction is for the National Endowments. the Smithsonian, and the Corporation for Public Broadcasting, rather than for the conduct of education and training.

The Older Americans program is excluded because it is geared mainly to provide part-time public service employment for low-income older workers, not to develop their skills. Funds for other labor services are excluded because they are used largely to compile labor statistics and regulate employer/employee relations. These labor services may be considered as investments in that they contribute to the economic infrastructure, but they are not meant primarily to develop human resources. (Likewise, the enforcement of equal opportunity legislation is not included here, even though these laws are an important part of the infrastructure.)

The Second Category: Adding Social Services. The second category of federal expenditures that could be counted as investments in human capital would add social service programs to the list. These programs provide a broad range of services to individuals to help them develop their vocational abilities, as well as to achieve other purposes. Their link to the development of a more skilled and productive workforce is, in general, somewhat more distant than that of the programs in the first category.

The activities include Head Start, vocational and rehabilitation services, payments to states for foster care and adoption assistance, and the Social Services Block Grant. Including these expenditures would add almost $9 billion to the portion of the 1990 budget counted as human capital investment (see Table 4).

Again, decisions about which programs to include are judgment calls. Head Start, though classified in the social services part of the budget, is quite close to activities classified in the education category. It is intended to help preschool-aged children succeed in school by providing comprehensive educational, medical, nutritional, and other services to poor children to give them an "equal place at the starting line" when they begin school.

Federal support for vocational rehabilitation services is provided largely through grants to states authorized by the Rehabilitation Act of 1973, as amended. State agencies may use the funds to provide services to people with physical or mental disabilities if the assistance is expected to increase the participants' employability.

Other programs are more difficult to classify. For example, grants to states for foster care and adoption assistance support state efforts to reunite children with their families or to place them in adoptive homes. Outlays for these activities are included because of their potential effects on the development of the children involved.

Similarly, the Social Services Block Grant is included because states may use the money to fund social services--such as child care, foster care, and child protection--that contribute to the development of the children involved. But these funds can also be used for low-income home energy assistance--aid that is mainly for current consumption, not for investment.

Among the social services excluded are support for various volunteer programs and grants to states for services to refugees. They are not included as human capital investment because they are largely for other purposes. Nonetheless, some of the activities funded, such as the foster grandparent program, contribute to the development of the young people with whom the volunteers work.

The Broadest Category: Adding Food and Nutrition Assistance Programs. The broadest of the three categories of investments in human capital would also count programs that provide food or nutrition assistance on the grounds that by contributing to physical and mental health, they help recipients lead more productive lives. For example, the Special Supplemental Food Program for Women, Infants, and Children (WIC) is intended to reduce health problems associated with inadequate diets by providing food assistance and nutrition education. The National School Lunch, School Breakfast, and Child Care Feeding programs are intended to improve the health and well-being of children and their ability to learn by providing them with nutritious meals. These programs alone would add over $7 billion to total federal spending classified as human capital investment (see Table 4).

A similar case could be made for adding Food Stamps (with outlays of about $15 billion in 1990) and perhaps other income security programs. The admittedly arbitrary distinction here is that nutrition programs such as WIC aim more directly at preventing or alleviating problems that would impede the recipients' subsequent development. Although providing food stamps to a destitute family might well have a similar effect, this result is not a specific purpose of the program.

Excluding Health Expenditures. Broader than any of the three formal criteria considered above, another interpretation of what constitutes an investment in human capital would include all or most health expenditures. This would greatly increase the estimated share of the federal budget used for human capital investment. In particular, the inclusion or exclusion of Medicaid is critical because expenditures on this program dwarf the amount spent on most of the programs discussed above. Although Medicaid is not conventionally viewed as an investment, many of the health services it funds meet a basic investment criterion: they provide participants with long-term benefits. It is not included in this study, however, because its impact on the productivity of the workforce is a more distant by-product.[6]

Excluding Expenditures on Federal Employees. In addition to the investments in human capital examined in this chapter, the federal government invests a considerable amount of resources in educating and training its employees. Although these activities clearly fit the definition of investments in human capital--that is, they increase the skills and productive knowledge embodied in people--they are outside the scope of this study. Their primary purpose is largely to achieve some other objective such as, in the case of national defense expendi-

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6. One could argue that Medicare and Social Security should also be included because they may improve the health and longevity of the participants. Because most of the participants have retired from the paid labor force, however, effects on their productivity would be incidental. (An exception might be the Social Security dependents' benefits provided for elementary and secondary school students under age 19.)

tures, protecting the United States and its allies from foreign aggression.

Many of these investments are likely to be inexpensive in terms of cost per worker, but large in total. With over 5 million people (including about 2 million military personnel on active duty) on the federal payroll, even a few days of training for each worker could add up to several billion dollars in forgone output and other training costs.

Some programs for federal employees are extremely intensive and expensive per worker. The military service academies, in particular, provide four years of college education, with pay, to their students in return for their agreeing to serve a minimum of six years on active duty after graduation. In 1989, the average cost incurred by the Department of Defense was about $200,000 per graduate.[7]

RETURNS ON INVESTMENTS IN HUMAN RESOURCES

The remainder of this chapter examines the basis on which federal investments in human capital have been evaluated and provides a partial survey of the results of studies of their effectiveness. Illustrations of program evaluations are drawn from the research on job training programs--the set of programs for which impacts on the participants' subsequent earnings have received the most attention.

Evidence from Production-Function Studies

In recent years, stories of a population ill prepared to function in today's or tomorrow's workplace and unable to compete with the workers of other nations have become commonplace. Foundations, business and labor organizations, and government advisory bodies have issued numerous reports calling for improvements in the education and training of the U.S. population to enhance the nation's economic performance.

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[7] Congressional Budget Office, "Officer Commissioning Programs: Costs and Officer Performance" (June 1990). In 1989, the average cost per graduate was $153,000 at the Naval Academy, $225,000 at the Air Force Academy, and $229,000 at the Military Academy.

The importance of human capital to the growth of the U.S. economy has been well established. Studies by Denison, for example, attribute about one-quarter of the growth in output per worker between 1929 and 1982 to the increase in the level of education of the workforce. During this period, real national income per worker increased at an annual rate of about 1.5 percent, with increased educational attainment alone accounting for an estimated 0.4 percent annual increase.[8]

The contribution of the federal government's investments in human capital to economic growth could be estimated, in principle, from production-function studies like those discussed in Chapter II, but probably not in practice. A production-function approach would include these investments in a model of the nation's economic growth. Although several studies, such as Denison's, have estimated the importance of human capital to economic growth, none has specifically linked this growth to the government portion of investments in human capital. The federal investment is probably too small to make such an approach viable.

Empirical evidence linking the level of public spending (federal, state, and local combined) on investments in human capital to the nation's economic performance is tenuous. Part of the problem has to do with uncertainty about the connections between the amount spent on students, the amount that they learn, and their subsequent productivity. A survey of the literature on the economics of schooling found little, if any, convincing evidence that student achievement is correlated, for example, with teacher-to-student ratios.[9]

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[8] Edward F. Denison, *Trends in American Economic Growth, 1929-1982* (Washington, D.C.: Brookings Institution, 1985), pp. 30 and 113.

[9] Eric Hanushek, "The Economics of Schooling: Production and Efficiency in Public Schools," *Journal of Economic Literature*, vol. 24 (September 1986), pp. 1141-1177. But see David Card and Alan Krueger, "Does School Quality Matter?" National Bureau of Economic Research Working Paper No. 3358 (May 1990), for evidence that higher teacher-to-student ratios may make a difference in subsequent earnings.

Evidence from Cost-Benefit Studies

The more practical approach to estimating the returns from many of the federal government's investments is on a case-by-case basis using the cost-benefit approach described in Chapter I. The direct effects of specific programs on the subsequent behavior and activities of participants are estimated; these estimates are used to infer the impact on the economy's output, as well as on the achievement of other societal goals. A program expands output if its rate of return exceeds the rate that the resources it draws on would have achieved in alternative uses.

The cost-benefit approach to evaluating investments in human resource projects involves estimating the costs and the dollar values that the analyst assigns to the benefits over the life of the project. Using a discount rate to account for the productivity that resources would have in private investments or other alternative uses, a cost-benefit calculation then determines whether the project seems worthwhile. In particular, the discount rate is used to scale future costs and benefits to today's values, known as "present values." If the present value of all benefits exceeds that of the costs, the program would be productive. In principle, the distribution of the project's benefits and costs does not affect the assessment because if total benefits exceed costs, the winners could compensate the losers and still come out ahead.[10]

Using this criterion of economic efficiency, the main benefit of a training program is likely to be an increase in the future output of the participants that is attributable to the program. The main costs are the forgone output of the participants while in the program and the value of the time spent by the program's staff. Stipends to the participants would not count as a benefit or cost to society as a whole because the gains to the recipients are costs to the payers. (The cost of stipends might be used as a proxy for the participants' forgone earnings, however, in which case they would be counted as a program cost but still not as a benefit.)

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[10] This is an application of the Kaldor-Hicks principle in welfare economics. For a fuller explanation of the principles of benefit-cost analysis and their application to government decisionmaking, see Edward M. Gramlich, *A Guide to Benefit-Cost Analysis of Government Programs* (Englewood Cliffs, N.J.: Prentice-Hall, 1990).

Other benefits and costs to society as a whole can be included within this general framework even if they are not commonly viewed as economic effects. For example, a benefit found in the evaluation of the Job Corps (discussed below) is that the participants committed fewer serious crimes. A benefit reported by evaluators of work-related programs for mothers who were receiving means-tested benefits is their increased self-esteem. Although such benefits are usually difficult to quantify, they are nonetheless real.

Evaluations of investments in human resources generally go beyond this framework to consider the distribution of benefits and costs attributable to the investments--factors that have little to do with the programs' effects on the economy. A common way of making such an evaluation is to estimate the effects of a program from different perspectives--especially from the perspective of the participants themselves and from that of the federal budget (or taxpayer). Two questions that these evaluations typically ask are whether the participants are better off and whether the costs incurred by the government are subsequently offset by reduced expenditures on transfer programs.

Results of Cost-Benefit Studies. Decisions about whether particular programs should be expanded, cut, or refocused can be based in part on information about a program's previous impacts. An extensive evaluation literature exists, covering many of the programs in the three areas described in the preceding section.[11] Overall, the results are mixed and quite difficult to generalize.

The evaluations have mainly looked at the effects of specific federally assisted programs on the subsequent behavior and well being of the participants. For some of the programs counted as investments under the first criterion discussed above--notably the training pro-

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[11] Recent reviews of the literature on evaluation of various human resource programs include John G. Wirt and others, *Final Report of the National Assessment of Vocational Education*, 5 vols. (Department of Education, 1989); Head Start Synthesis Project, *The Impact of Head Start on Children, Families and Communities*, Final Report (Department of Health and Human Services, 1985); National Research Council, *Youth Employment and Training Programs: The YEDPA Years* (Washington, D.C.: National Academy Press, 1985); Burt Barnow, "The Impact of CETA Programs on Earnings: A Review of the Literature," *Journal of Human Resources*, vol. 22 (Spring 1987), pp. 157-193; Congressional Budget Office, *Work-Related Programs for Welfare Recipients* (1987); and Select Committee on Children, Youth, and Families, U.S. House of Representatives, *Opportunities for Success: Cost Effective Programs for Children: Update, 1988* (1988).

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grams--evaluations have examined the impact on the participants' subsequent earnings. Overall, the training programs evaluated appear to have been successful in increasing the average earnings of participants, although the gains have been modest.[12] Under certain assumptions (discussed below), an estimated positive impact on earnings can be treated as its effect on economic growth as well.

Evaluations of most of the social services and food and nutrition assistance programs counted as investments under the broader criteria discussed above have focused on impacts less directly related to economic growth. In general, the programs evaluated appear to be successful in achieving specific objectives. For example, evaluations of Head Start indicate it has immediate positive effects on the cognitive development of the participating children, although these effects appear to diminish.[13] WIC appears to have increased the average birthweight of infants born to participating mothers and reduced the incidence of preterm births.[14] Whether achieving the programs' objectives ultimately increases gross national product is not known, nor would it be appropriate to judge them only by this standard.

Evaluation Methodology. A common procedure for evaluating a training program is to estimate its effects on the subsequent compensation of the participants. It is then assumed that any increase in their compensation attributable to the program reflects a corresponding increase in their production of goods and services. Moreover, it is assumed that participants' increased output was not at the expense of that of nonparticipants--that is, that no displacement occurred. With these assumptions, the estimate of the program's impact on participants' future compensation also provides an estimate of its impact on gross national product.

The assumption of no displacement is important, but cannot be tested. Displacement is a concern because increasing participants' employability and job search skills does not directly expand the number of jobs employers offer, although employers might be able to fill jobs more rapidly--especially in labor markets with low unemployment rates. Even if all the participants obtained jobs that would otherwise have gone to nonparticipants, a program might still be worth doing on distributional grounds. But, if that were the case, the standard methods of evaluation would overestimate the program's impact on total output.[15]

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[12] Barnow,"The Impact of CETA Programs on Earnings."

[13] Head Start Synthesis Project, *The Impact of Head Start*, p. 22.

[14] Select Committee on Children, Youth, and Families, *Opportunities for Success*, p. 9; and Mathematica Policy Research, Inc., *The Savings in Medicaid Costs for Newborns and Their Mothers from Prenatal Participation in the WIC Program*, vol. 1 (Washington, D.C.: Mathematica, October 1990).

Another major problem in evaluating human resource investments is the uncertainty concerning what would have happened to the participants if the program had not been available to them. This information is needed in order to estimate the net impact of the program on their subsequent behavior. Knowing that the participants found jobs is not enough, for example, because presumably at least some of them would have done so even without the program.

Much of the literature on evaluation methodology in recent years has been concerned with how to construct an appropriate comparison group. Most researchers would probably agree that evaluations based on experimental designs in which potential participants are randomly assigned to the program or to a control group are preferable to other techniques. But such experiments are not always feasible, particularly for evaluations of ongoing programs. The first evaluation examined in this section used a nonexperimental design; the second evaluation was based on a set of experiments with random assignment.

The specific studies examined below have figured prominently in public policy debates, and illustrate the state of the art of program evaluation. The first is an evaluation of the Job Corps, the results of which appear to have been influential in determining appropriations for the program. The second is a set of evaluations of work-related programs for welfare recipients that was widely cited in the discussions of welfare reform leading to the enactment of the Family Support Act of 1988.

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[15] The displacement issue and other issues in evaluating human resource programs are examined in greater detail in Congressional Budget Office, *Work-Related Programs for Welfare Recipients*, pp. 31-34.

Job Corps. The Job Corps is perhaps the most intensive large-scale federal program whose main purpose is to increase the future earnings of a low-income group. In 1991, the program is providing education, training, and other assistance in a residential setting to almost 70,000 youths, at a cost to the taxpayer of over $12,000 per participant.

Partly because of its high costs per participant, the Job Corps was the subject of a comprehensive evaluation in the late 1970s and early 1980s.[16] The results of the study (conducted by Mathematica Policy Research, Inc., for the Department of Labor) have been widely cited and acknowledged as valuable in maintaining Congressional support for the program during a period in which funding for other employment and training programs was being sharply curtailed.[17]

Several characteristics of the Job Corps and of Mathematica's evaluation make the estimates from that study especially useful for illustrating how investment in human capital might affect economic growth. First, the program itself is of interest because its federal costs per participant are relatively large and because it focuses on improving the participants' job prospects. Second, most of the investment is undertaken directly by the federal government, rather than by the participants themselves, and is not used to supplement state and local activities. Third, the evaluation provides considerable information about the key dimensions for assessing the economic returns to an investment in human capital. Finally, the methodology on which the findings are based has been extensively reviewed and generally supported by other analysts.[18]

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16. Results reported here are based on Mathematica Policy Research, Inc., *Evaluation of the Economic Impact of the Job Corps Program: Third Follow-Up Report* (Washington, D.C.: Mathematica, September 1982). That report, based on data for up to four years after participation in the program, generally confirmed and strengthened earlier findings.

17. Joseph Wholey, "The Job Corps: Congressional Uses of Evaluation Findings," *Evaluation Studies Review Annual*, vol. 12 (1987), pp. 234-244.

18. The National Research Council, in its review of lessons from a wide range of youth employment and training programs operating in the late 1970s, concluded that the Job Corps was the only ongoing program for which there was "sufficient reliable evidence to assess the efficiency. . .with which youth programs achieved their effects." See National Research Council, *Youth Employment and Training Programs*, p. 16.

The estimates of program impacts were based on extensive information collected in interviews with about 5,000 youths who participated in the Job Corps in 1977 and about 1,500 youths with similar backgrounds who had not enrolled because they had little or no knowledge about the program. The comparison group was drawn from locations similar to those where the participants had been living, but in which program operators had not recruited heavily. Statistical techniques were used to attempt to adjust for any remaining differences between the two groups that might have affected the results.[19]

Based on Mathematica's findings (using their benchmark assumptions and converting their estimates into 1990 dollars), the Job Corps appears to have been a good investment. For about $10,000 in resources invested in the average participant in the year the program was evaluated, society obtained a stream of benefits whose "present value" (with a real discount rate of 5 percent) was worth almost $15,000.[20] As discussed below, reductions in crime, rather than increases in output, accounted for a substantial part of the estimated benefits.

Reviewing the main components of these estimated costs and benefits helps one understand both the nature of programs that invest in human capital and their assessment (see Table 5). The investment costs were mainly those incurred by the federal government to operate the residential centers, including the compensation of teachers and other staff. The largest cost of many education and training programs is the output forgone by the participants while in the program. Because Job Corps participants were mostly poor youths who had not finished high school, their forgone output was rather small--similar to the value of the output produced by participants in the work experience and on-the-job training components of the program.

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[19] The methodology is described in Mathematica, *Evaluation of the Impact of the Job Corps Program*, pp. 36-65.

[20] A benefit to be received in the future is not worth as much as the same benefit received today, even after adjusting for inflation. A standard procedure used by evaluators is to equate benefits and costs incurred in different years by discounting the future impacts. The "present value" of future benefits estimated by Mathematica was calculated by counting a dollar to be received one year in the future as equivalent to $0.95 received today.

TABLE 5. RESOURCES INVESTED IN THE AVERAGE JOB CORPS PARTICIPANT IN 1977 AND THE ECONOMIC RETURNS ON THE INVESTMENT (In 1990 dollars)

Source of Impact	Present Value[a]	Impact During Program	Impact Following Termination			
			First Year	Second Year	Third Year	Fourth Year
Costs to the Economy						
Program operating costs (Other than transfers)	8,380	8,380	0	0	0	0
Forgone output of participants	1,760	1,760	0	0	0	0
Total Costs	10,140[b]	10,140[b]	0	0	0	0
Benefits to the Economy						
Increased output of participants	8,080	1,520	600	1,500	1,300	940
Reductions in cost of crime-related activities	5,840	2,020	1,200	940	1,260	780
Reductions in costs of operating other programs	880	540	160	20	40	80
Total Benefits	14,800	4,080	1,960	2,460	2,600	1,800
Net Impact on the Economy	4,660					

SOURCE: Estimates by the Congressional Budget Office based on data from Mathematica Policy Research, *Evaluation of the Economic Impact of the Job Corps Program: Third Follow-up Report* (Washington, D.C.: Mathematica, September 1982).

NOTE: Amounts are expressed in 1990 dollars by adjusting the original estimates for inflation since 1977.

a. Present value is based on a 5 percent real discount rate and assumes that the impact on earnings estimated for the fourth year will decline by 14 percent per year, falling below $100 by the eighteenth year.

b. Excludes about $2,800 in costs the government incurred for cash or in-kind payments to participants, such as food and clothing, that Mathematica considered to be transfers between the government and the participants, rather than costs to society.

The largest estimated benefit to the economy from the program was the increased goods and services produced by the participants as a result of their experience. The Job Corps increased participants' earnings by about $1,000 per year on average during the four years in which they and the group of nonparticipants with whom they were being compared were interviewed. Assuming that their compensation equaled their contribution to the value of the goods and services they produced and that no net displacement occurred, this estimate represents a net increase to GNP directly attributable to the investment.

It is highly unlikely that the earnings gains resulting from participation in the Job Corps would have ended in the fourth year, but there is no way of knowing just what would have happened. Mathematica's baseline assumption is that the effects estimated for the final six months of the observation period would have declined at an annual rate of 14 percent thereafter--a fairly conservative approach. Together with the use of a 5 percent discount rate, this rate of decline implies that most of the gains from the program would have ended within 10 years after the observation period.

The other major benefit to society estimated by Mathematica is a reduction in major crimes committed by the participants while in the program and thereafter. Mathematica's treatment of the benefits of crime reduction illustrates the difficulty in measuring many of the effects of human resource investments. Based on the economic efficiency criterion discussed above, the estimated costs of crime to society (and, hence, the benefits to society of reductions in crime) included the costs associated with the criminal justice system, personal injury and property damage, and the portion of the value of stolen property lost as a result of the crime (the difference between the value of the property to the criminal and to the original owner). The emotional distress associated with being the victim of a crime was also noted as a cost, but its value was not estimated.[21]

A substantial decrease in the likelihood of committing a murder accounted for about half of the estimated benefit to society attributed to reductions in criminal activities. Mathematica estimated that participation in the Job Corps reduced the number of arrests for murder by about one per 100 hundred participants over five years.[22] The dollar value to society of a reduction in homicides was estimated and included as a program benefit. Mathematica's estimate was based largely on the value of the output the victims would have produced had they lived. Regardless of the magnitude of the contribution to the nation's output that results from fewer homicides (which depends on the forgone output of the victims), most people would count this as a substantial gain to society.

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[21] Mathematica's methods for estimating the value of the reduction in criminal activities are summarized in Mathematica, *Evaluation of the Impact of the Job Corps Program*, pp. 228-235.

Work-Related Programs for Welfare Recipients. A recent series of evaluations of special programs for recipients of Aid to Families with Dependent Children (AFDC) illustrates the state of the art in program evaluation techniques and the use of such studies for decisions about investments in human resources. The Manpower Demonstration Research Corporation (MDRC) conducted evaluations of programs developed in several states that were intended to increase the earnings of AFDC recipients and reduce their dependence on government transfer payments. Most of these studies used random assignment of recipients either to treatment groups that might receive assistance in education, training, job search, and work experience activities, or to control groups.

Results from most of the studies available in time to be used in the debates before passage of the Family Support Act were generally positive.[23] AFDC recipients assigned to treatment groups subsequently had higher earnings and lower welfare payments, on average, than recipients assigned to the control groups. These and other findings from the experiments were widely cited as evidence that the types of work-related requirements being considered by the Congress could be effective.

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[22] Mathematica, *Evaluation of the Impact of the Job Corps Program*, p. 233. The Job Corps was estimated to have reduced the number of arrests for murder by 2 per 1,000 participants while in the program; 4 per 1,000 in the first year after participation; and about 2 per 1,000 in each of the following three years. Arrests for other major crimes such as robbery and felonious assault also fell, although arrests for less serious offenses, such as burglary and traffic violations, increased.

[23] Results available through 1986 were summarized in Congressional Budget Office, *Work-Related Programs for Welfare Recipients*. For results from more recent evaluations, see Daniel Friedlander and Judith Gueron, *Are High-Cost Services More Effective Than Low-Cost Services? Evidence from Experimental Evaluations of Welfare-to-Work Programs* (New York: Manpower Demonstration Research Corporation, 1990).

The Job Opportunities and Basic Skills Training (JOBS) program, authorized by Title II of the Family Support Act, establishes a new program of work, training, and education for AFDC recipients. The new program, which replaces the Work Incentive (WIN) program, is administered by state welfare agencies. The federal government provides at least 60 percent of the funding, up to a maximum of $1 billion in 1991. The JOBS program builds on the experiences and lessons learned from several programs and demonstrations conducted by states in the 1980s.

One of these demonstrations was conducted in San Diego from 1985 through 1987. This project, known as the Saturation Work Initiative Model (SWIM), provided AFDC recipients with job search assistance, unpaid work experience, and education or training. Participation was mandatory. A recent study of SWIM by the Manpower Demonstration Research Corporation provides additional information about the effects of work-related programs for welfare recipients and further illustrates techniques for evaluating public investments in human capital.[24]

The evaluators' estimates suggest that SWIM was a good investment for society, as measured by a comparison of the value of the resources invested in the average participant with the increased output of the participant attributable to the program (see Table 6). The net cost per member of the treatment group was about $900, a small portion of which was for transfer payments (and was therefore not included as a cost to the economy). The present value of the additional

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24. Gayle Hamilton and Daniel Friedlander, *Final Report on the Saturation Work Initiative Model in San Diego* (New York: Manpower Demonstration Research Corporation, November 1989). The study differs from the Job Corps evaluation that was reviewed above in at least two important respects. First, it is based on random assignment of eligible AFDC recipients to an experimental group or to a control group, thereby making it possible to isolate the program's effects. Second, the members of the experimental group were all subject to the rules of the experiment, but did not necessarily participate in any of the work-related activities. Thus, both the estimated costs of the program and its benefits are the effects of being in a treatment group--not of actually receiving assistance. This was done because members of the SWIM treatment group were subject to stronger work-related requirements as a condition for continued receipt of AFDC than were members of the control group.

output produced within five years (as measured by higher earnings and fringe benefits) was about $2,400 per person, including a small amount of output by the participants in on-the-job training and work experience activities.

TABLE 6. ESTIMATED IMPACTS OF THE SWIM EXPERIMENT OVER FIVE YEARS, FROM THREE PERSPECTIVES (In 1986 dollars)

	Perspective		
Source of Impact	Economy	Budget	Participant
Program Operating Costs (Other than payments to participants)	-850	-850	0
Payments to Program Participants	0	-70	70
Participants' Output While in Program	180	180	0
Subsequent Output of Participants	2,230	0	2,230
Tax Payments by Participants	0	80	-80
Reductions in Welfare Payments to Participants	0	2,180	-2,180
Reduction in Costs of Operating Other Programs	50	50	0
Net Impact per Participant	1,610	1,570	40

SOURCE: Congressional Budget Office using data based on Gayle Hamilton and Daniel Friedlander, *Final Report on the Saturation Work Initiative Model in San Diego* (New York: Manpower Demonstration Research Corporation, November 1989), p. 126.

NOTES: The numbers in this table are MDRC's estimates of the average impacts for recipients of Aid to Families with Dependent Children (AFDC) who were in the experimental group. Data are based on two to three years of observations. Projections were made for the remainder of the five-year period based on the assumption that the program's effects decline by 22 percent a year. Alternative projections based on the assumption that the effects continue unabated for the remainder of the five-year period add about $300 to the estimated present value to the economy.

A negative number indicates that the estimated impact is a cost.

Additional findings from this study underscore some of the difficulties in interpreting and making judgments about investments in human resources. One purpose of work-related programs for welfare recipients is to reduce the net burden that welfare recipients place on the federal budget. The estimates reported in Table 6 suggest that SWIM was quite successful in this regard. Reductions in welfare payments to the treatment group within a five-year period were estimated to exceed the costs of the program substantially.

Another purpose is to improve the economic well-being of the participants. The estimates reported in the table suggest that SWIM was not as successful in achieving this objective. The higher earnings and fringe benefits of members of the treatment group were offset by reductions in welfare payments and increased tax payments of a similar magnitude. As a consequence, the average income of the treatment group, as a whole, was little changed by the program--by only $40 per participant--although within the group some gained and others lost. Even members of the treatment group whose total incomes were no higher as a result of working rather than receiving welfare may have felt better off because of increased self-esteem, for example. But, at least in the short run, their gains were more psychological than economic.

CONCLUSIONS

Viewing federal spending on education, training, social services, and food and nutrition assistance as investments in human capital raises three questions that cannot be answered well: Are they good investments? Is additional investment in these activities warranted? Are there changes in the way the current funding is being used that would increase the returns?

The answers to these questions depend critically on what counts as returns and how they are valued. Because most of the human resource programs were designed for purposes other than economic growth, assessment based only on their contribution to output would be misleading. In the case of the SWIM demonstration program, for example, reduction in welfare payments was a major goal and was achieved.

SWIM also appears to have been a good economic investment, but even if this had not been the case, the program may have been judged worthwhile on other grounds.

Moreover, most federal outlays for activities counted as investments under the three categories described earlier in this chapter are for programs whose effects are more difficult to gauge. For example, most federal support for elementary, secondary, and vocational education supplements much larger amounts of state and local spending; it is difficult to separate the contribution of the federal share from that of the total. Even determining the net addition to spending that results from these federal programs is difficult. A similar problem exists in determining the extent to which grants and loans to students in postsecondary education add to their educational attainment, rather than substitute for private spending.[25]

For activities such as the ones examined here that can be evaluated, the evaluations can play a useful role in helping the Congress and others decide whether the activities are meeting their objectives and whether changes in program design might increase returns. For example, as states begin to implement the JOBS program created by the Family Support Act, they can draw on the results from the various experiments to guide them in decisions about the most effective types of work-related programs.

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[25] See Michael S. McPherson and Morton Owen Schapiro, "Does Student Aid Affect College Enrollment? New Evidence on a Persistent Controversy," *American Economic Review*, vol. 81 (March 1991), pp. 309-318.

CHAPTER IV

FEDERAL INVESTMENT IN INTANGIBLE ASSETS: RESEARCH AND DEVELOPMENT

A third type of asset in which society can invest to expand its economic prospects is intangible capital--the body of knowledge that leads to new and better products and techniques of production. In the years since World War II, the federal government has sought actively to expand the body of intangible capital by supporting research and development (R&D).

In 1990, the federal government spent $67 billion on R&D, reimbursed part of the R&D expenses of private firms contracting with the government, and granted tax preferences to private firms conducting R&D. Most spending supported the missions of the federal agencies making the direct expenditures--for example, defense, space exploration, or health. Much of the rest supported pure research and other efforts to maintain and extend the nation's science and technology base. A small amount supported R&D intended to enhance economic productivity.

In its budget proposal for 1992, the Administration has requested an increase of 13 percent, or $8.4 billion over the 1991 level of spending for R&D. Applied research and development for the Department of Defense accounts for 65 percent of the total increase--$5.4 billion. Consistent with recent trends, the largest proposed increase for a civilian agency goes to the National Aeronautics and Space Administration, which accounts for over one-half of the $2.5 billion increase in total civilian-related R&D. The request for a 16 percent increase in the basic research budget of the National Science Foundation is also noteworthy.

Studies of the rate of return to academic and basic research, most of which is federally funded, suggest that it significantly increases the nation's productivity. Such research represents about one-quarter of all federal spending for R&D. In some areas of applied research and development, such as health or agriculture, federal funding also appears to generate measurable returns. The evidence on the return to federal funding of other areas of applied R&D is mixed, with no consistent evidence of significant returns.

The lack of clear evidence of a payback for most federally funded R&D may result from the difficulty of measuring these returns. Failure to find measurable economic returns for most federal R&D does not, in itself, invalidate those programs, however. Most federal R&D is undertaken to promote the mission of the agency that funds it and is best evaluated on the basis of its contribution to the agency's mission rather than any purported ancillary economic benefits.

RATIONALES FOR FEDERAL SUPPORT OF R&D

Although technological progress has been responsible for most of the historical improvement in the material well-being people enjoy, the idea that ongoing government policy can encourage such progress is a relatively new one. Material improvement began to proceed especially rapidly in the Western world by about the mid-1700s, when accumulated scientific and technological knowledge was purposefully applied to innovation. Developments in the West since that time have led to an estimated tenfold increase in per capita real income and a doubled life expectancy at birth.[1] Yet public spending to support science and technology was on a small scale before World War II. Since the war, however, federal spending for R&D has grown significantly, and it now accounts for over 5 percent of federal purchases.

Promoting Agencies' Missions

The rationale for most federal support for R&D stems from the specific missions of federal agencies in producing public goods such as national defense and public health. The unique characteristic of a public good--whether a product or a service--is that it can be consumed by an individual without diminishing the amount available for other individuals to consume. Because of this characteristic--an extreme form of the spillover effects that are discussed in earlier chapters--economists believe that, left to itself, the market will lead to insufficient production of "pure" public goods. They argue, therefore, that government can make society better off by providing public goods itself. Much of the government's R&D is intended to help it produce public goods better and more efficiently. However, public goods are difficult to value--how much, for example, is national security worth in dollar terms? Accordingly, calculating the return to R&D and other expenditures devoted to production of such goods is problematic.

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[1] See Nathan Rosenberg and L.E. Birdzell, Jr., "Science, Technology and the Western Miracle," *Scientific American* (November 1990), pp. 42-54.

Promoting the Generation of Knowledge

A second rationale for federal support of R&D emphasizes that knowledge itself is a public good, regardless of whether that knowledge serves the specific mission of a federal agency. Individuals can use scientific knowledge without decreasing its availability for others. Once technological knowledge is gained, the additional cost of transferring it to others is usually negligible.

Whether produced by the public or the private sector, new knowledge is difficult to contain. But private investors will generally produce knowledge only to the extent that they can directly profit from it. Any additional benefits that spill over and accrue to others are not a factor in the decisions of private investors to invest in R&D. In these cases, the social return (total benefit to society as a whole) is greater than the private return (benefit to the investor alone). Federal support can therefore assist society by providing or encouraging more investment in R&D. Evidence for this rationale is offered by studies indicating a higher social return than private return to private R&D spending, and a higher social return to investment in academic research than to investment in physical capital.

Overcoming Risk

A less widely accepted rationale for federal support for R&D is that only the federal government can undertake enough R&D to offset the risks that this type of investment entails. One study calculated that, for a typical firm, the undiversified risk of investment in R&D is two or three times that of investment in physical capital.[2] Some analysts argue that private firms will often decide not to undertake socially worthwhile R&D projects because they consider them to be too risky. The only way to reduce this risk is to diversify by undertaking many separate R&D projects. According to some analysts, only government is able to invest widely enough in R&D to allow this diversification to operate effectively.[3]

TRENDS IN FEDERAL SUPPORT FOR RESEARCH AND DEVELOPMENT

The federal government spent $67 billion on R&D in 1990, accounting for about 46 percent of all R&D spending in the U.S. economy.[4] Private industry accounted for 49 percent, and universities and other nonprofit institutions accounted for 5 percent.[5] The federal government spent substantially more than nonfederal entities through the 1950s and 1960s, but the federal share slipped during the 1970s. Nonfederal

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[2] Gerard Wedig, "How Risky is R&D? A Financial Approach," *Review of Economics and Statistics* (May 1990), pp. 296-303.

[3] Others, however, argue that the advantage of being first in the market with a new product may lead firms to undertake too much risky R&D. For contrasting views, see Partha Dasgupta and Joseph Stiglitz, "Uncertainty, Industrial Structure, and the Speed of R&D," *The Bell Journal of Economics*, vol. 11 (Spring 1980), pp. 1-28; and Tor Kletta and David de Meza, "Is the Market Biased Against Risky R&D?" *Rand Journal of Economics* (Spring 1986), pp. 133-139. In addition, some argue that market structure and incentives may lead to socially wasteful R&D efforts. See Morton J. Kamien and Nancy L. Schwartz, *Market Structure and Innovation* (New York: Cambridge University Press, 1982), pp. 187-193.

[4] For a more complete discussion of the trends and history of R&D spending in the United States, see Congressional Budget Office, *Using Federal R&D to Promote Commercial Innovation* (April 1988), Chapter II. The various National Science Foundation data series use slightly different definitions because they are collected from different surveys for different purposes. Consequently, there may be nontrivial discrepancies between data series. For instance, federal R&D spending for 1990 totals $63.8 billion, $66.08 billion, $68.5 billion, or $69.2 billion, depending on the NSF data series.

[5] National Science Foundation, *National Patterns of R&D Resources: 1990*, Final Report, by J.E. Jankowski, NSF 90-316 (1990), p. 47.

R&D exceeded federal R&D for the first time in 1978, and was about $5 billion to $10 billion above federal R&D throughout the 1980s.

Federal spending for R&D has an uneven history. After quadrupling between 1953 and 1967, real federal R&D shrank for the next eight years (see Figure 5). Only in 1976 did real federal spending begin to climb again, finally exceeding the 1967 level in 1984. Between 1985 and 1990, real federal R&D grew at an annual rate of 2.3 percent. Expressing federal R&D as a share of gross national product makes the shrinkage appear more pronounced and the recovery look more sluggish (see Figure 5).

Changes in spending for R&D in space and defense explain most of the fluctuation in total federal R&D spending. The Apollo program accounted for the upward spike in inflation-adjusted federal R&D spending in the mid-1960s. The more modest space effort of the 1970s received far less funding, and only after 1985 did R&D spending for civilian space efforts begin to grow again. Defense's share of total R&D also has varied substantially over time. In 1990, almost two-thirds of all federal R&D spending was for national defense, either at the Department of Defense (DoD) or at the Department of Energy (DOE).[6] In 1960, defense R&D accounted for over 80 percent of all federal R&D.[7] By the mid-1960s, however, the defense share had fallen to roughly half of all federal spending on R&D, where it remained until the military buildup of the early 1980s. During the 1980s, defense R&D accounted for slightly more than two-thirds of all federal R&D, and only recently has its share begun to decline.

Some analysts believe that the federal commitment to productivity-enhancing R&D could be measured more accurately if federal spending for defense R&D were removed from total federal R&D. As Figure 6 shows, federal spending for nondefense R&D as a share of GNP peaked in the mid-1960s, reflecting spending for the Apollo program, and has remained at about 0.5 percent of GNP since the mid-

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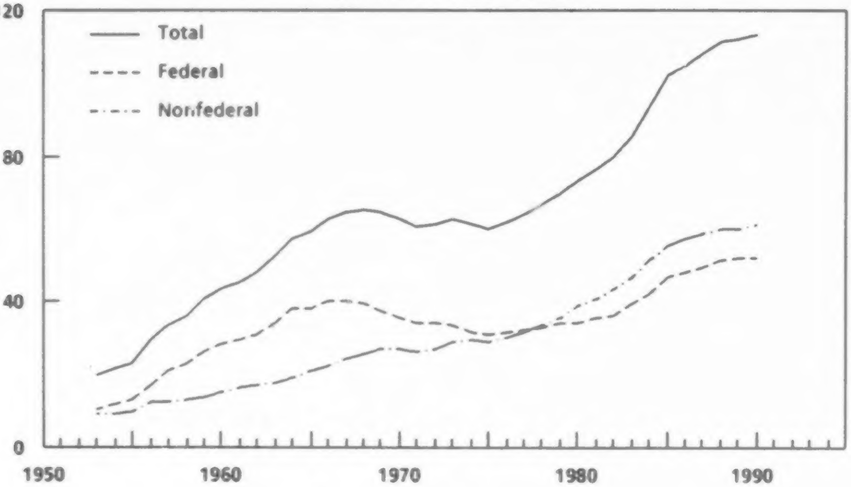
[6] National Science Foundation, *Federal R&D Funding by Budget Function, Fiscal Years 1989-1991*, NSF 90-311 (April 1990), p. 2.

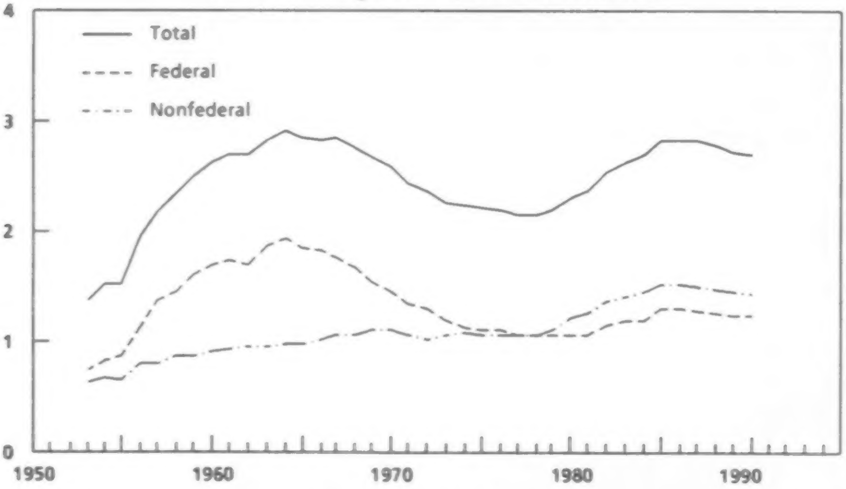
[7] National Science Foundation, *Federal R&D Funding*, p. 120.

Figure 5.
Federal and Nonfederal Spending for Research and Development, 1953-1990

In Billions of 1982 Dollars



As a Percentage of Gross National Product



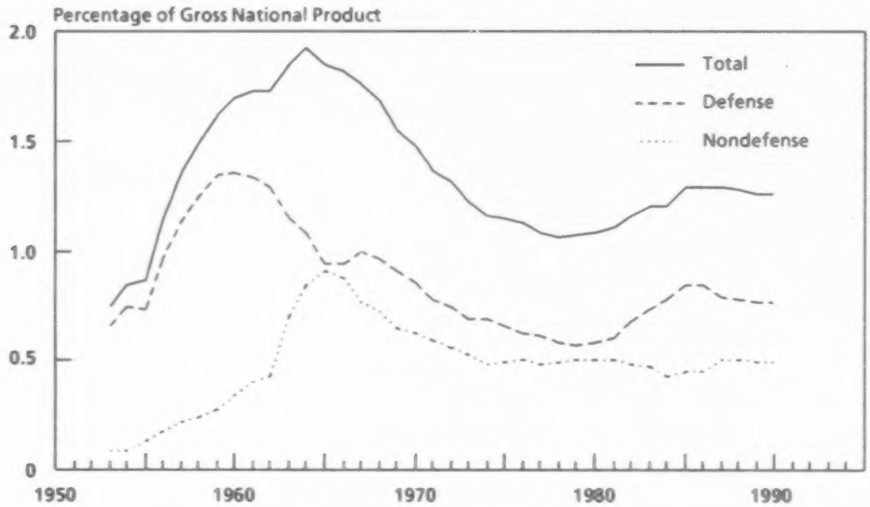
SOURCES: Congressional Budget Office using data from National Science Foundation, *National Patterns of R&D Resources: 1990*, Final Report, by J.E. Jankowski, NSF 90-316 (1990), pp. 47 and 55.

1970s. The defense share peaked at about 1.4 percent of GNP in 1960 and has averaged about 0.7 percent of GNP since the mid-1970s.

Other areas of R&D have also experienced noteworthy changes in their share of total federal R&D. R&D for health grew from 4 percent of all federal R&D in 1960 to 12 percent in 1980, a share it has maintained over the last decade by keeping pace with increases in R&D at the Defense Department. Energy R&D, after a bulge of spending in the late 1970s and early 1980s, headed back to its traditional 3 percent to 4 percent of all R&D. Space, which accounted for over one-quarter of all federal R&D in the late 1960s, fell to 5 percent in the 1980s, but rose to 8.7 percent by 1990.

Most federal R&D spending is motivated by perceptions of both national needs and technical opportunities. The history of federal

Figure 6.
Federal Spending for Defense and Nondefense Research and Development, 1953-1990



SOURCES: Congressional Budget Office using data from National Science Foundation, *National Patterns of R&D Resources: 1990*, Final Report, by J.E. Jankowski, NSF 90-316 (1990), p. 55.

spending for R&D provides useful background, but movements in either the absolute or relative amount of spending are not necessarily meaningful in themselves. Instead, most of the ups and downs occur as either the needs or opportunities change. For instance, much of the bulge in R&D for energy represented a response to restricted supplies of oil, and spending for research on superconducting materials increased recently in response to technological breakthroughs.

Federal Spending by Type of Activity

Although classifications are necessarily somewhat arbitrary, R&D has traditionally been divided into three categories--basic research, applied research, and development.[8]

- Basic research is performed to advance knowledge without regard to specific applications. Research on the behavior of subatomic particles or the structure of the human genetic code, for example, is basic research.

- Applied research is conducted to advance knowledge necessary to develop a new product or process. Examples include exploring the properties of materials to learn how to produce a more corrosion-resistant steel, or studying the properties of circuits to learn how to improve television reception.

- Development is undertaken to incorporate new knowledge into products and processes, including the design and production of prototypes.

Development programs dominate federal spending for R&D, although the relatively small share devoted to basic research has grown fairly steadily (see Figure 7). In 1990, development programs accounted for two-thirds of federal R&D spending.[9] (This share is large

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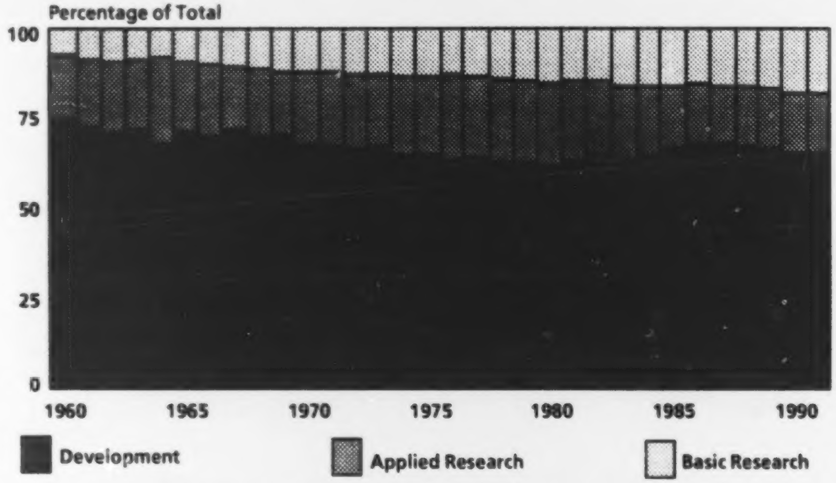
[8] See National Science Board, *Science and Engineering Indicators--1989* (Washington, D.C., 1989), p. 89.

[9] National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables, Fiscal Years 1955-1990* (1990), p. 21.

Figure 7.
Federal R&D Spending by Type of Work, 1960-1991



SOURCES: Congressional Budget Office using data from National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables, Fiscal Years 1955-1990* (1990), pp. 96-97; National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990, and 1991*, NSF 90-327 (December 1990), Tables 4, 5, and 6.

because about 90 percent of defense-related R&D is devoted to the development of weapons systems.) The remaining third was divided roughly equally between applied and basic research. In the 1950s and throughout much of the 1960s, development spending accounted for three-quarters of federal R&D, again a consequence of space and defense spending. Since then the growing share of basic and applied research has been led by biomedical research at the National Institutes of Health.

Federal Spending by Performer

Most federally funded R&D is not performed by the federal government, a characteristic that is unique to the U.S. system. In 1990, only 25 percent of federal spending for R&D, or $16.7 billion, was devoted to government-performed, or "intramural," R&D.[10] Industry carried out

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[10] National Science Foundation, *National Patterns of R&D Resources: 1990*, p. 43.

47 percent of federally funded R&D ($31 billion), most of which was for product development (for example, development of weapons systems). In 1990, 36 percent of all product development performed by private industry was federally funded. The federal government, universities, and colleges dominate basic research, accounting for over 80 percent of the $11.2 billion spent in 1990. Private industry undertakes the largest share of federally funded applied research--about 44 percent of the $13 billion spent in 1990.

Federal Spending by Agency

Five agencies accounted for about 95 percent of all federal R&D spending in 1990: the Department of Defense, $36.5 billion; the Department of Health and Human Services, $8.6 billion; the National Aeronautics and Space Administration, $7.5 billion; the Department of Energy, $6.7 billion; and the National Science Foundation, $1.9 billion.[11] In the past, other agencies have played greater roles in federal R&D spending than they now do, but rarely have these top five agencies accounted for less than 90 percent of federal R&D spending (see Figure 8).

Department of Defense. The R&D budget of the Defense Department grew by 85 percent between 1980 and 1990, even after adjusting for inflation. This increase followed a long period of decline; spending decreased by 30 percent between 1963 and 1975. R&D spending by the Pentagon increased most rapidly in the first half of the 1980s, registering annual growth of around 15 percent in both 1982 and 1985. The DoD influence on the total national R&D effort also includes $3.6 billion spent in 1989 for the independent R&D and bid and proposal programs. Under these programs, contractors undertake R&D projects of their own choosing, and DoD reimburses them to the extent it considers the projects to be of potential military value.[12]

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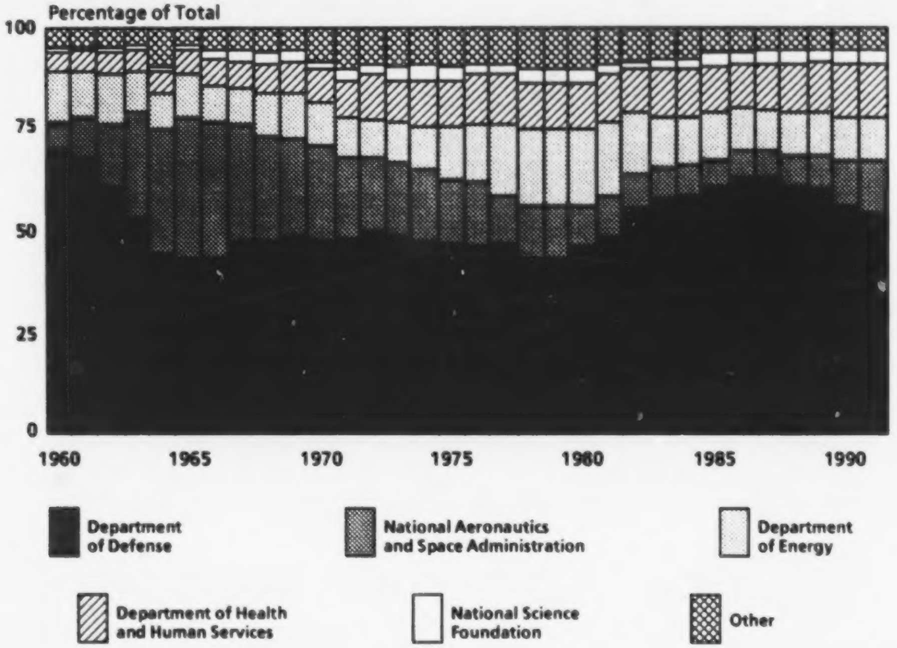
[11] National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990, and 1991* (December 1990), Table 2.

[12] Defense Contract Audit Agency, Department of Defense, "Summary: Independent Research and Development and Bid and Proposal Cost Incurred by Major Defense Contractors in the Years 1988 and 1989" (March 1990).

Figure 8.
Federal R&D Spending by Agency, 1960-1991



SOURCES: Congressional Budget Office using data from National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables, Fiscal Years 1955-1990* (1990), pp. 4-21, 76-89; National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990, and 1991*, NSF 90-327 (December 1990), Table 3.

Data on direct spending and other support for R&D by the Defense Department may overstate the department's commitment to R&D. Some analysts have argued that much of the "development" work performed under DoD auspices is not really an R&D activity, and outside of the military would be considered engineering support.[13] This characteristic of DoD spending for R&D is pertinent when considering its potential to increase productivity.

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[13] National Research Council, *Federal Science and Technology Budget Priorities: New Perspectives and Procedures* (Washington, D.C.: National Academy Press, 1988), p. 18.

The Defense Department spends most of its R&D budget for development, rather than for basic or applied research. In 1990, DoD devoted 90 percent of its R&D budget to development, accounting for over 80 percent of all federal spending for development. But the large size of DoD's total R&D budget--$36.5 billion in 1990--allows even the small shares of its spending devoted to basic and applied R&D (2.5 percent and 6.0 percent in 1990, respectively) to be significant, both in absolute terms and relative to other federal agencies. Its basic research spending of almost $1 billion accounted for 8.5 percent of federal spending for basic research. The $2.4 billion DoD spent on applied research in 1990 was the second largest amount for all federal agencies.

Most R&D funded by DoD is performed externally (outside of government agencies). In 1990, almost two-thirds of its R&D was allocated to industrial firms. Universities, nonprofit institutions, and federally funded R&D centers together received less than 10 percent of these funds directly. Only about 25 percent of DoD's R&D was performed internally. Historically, DoD has allocated between 60 percent and 70 percent of its R&D funds to industry.

Department of Health and Human Services. The R&D budget of the Department of Health and Human Services (HHS) grew by 40 percent between 1980 and 1990, after accounting for inflation. This growth allowed HHS to maintain its 12 percent share of federal R&D spending, up from only 4 percent in 1960.

About 90 percent of all R&D funded by HHS goes to the National Institutes of Health (NIH) to conduct in-house research and to fund university research. Most of NIH research focuses on the treatment of specific diseases. For example, the recent growth in overall funding for HHS has been driven by research into Acquired Immune Deficiency Syndrome (AIDS) and related diseases. Other health agencies within HHS--the Centers for Disease Control, the Food and Drug Administration, and the Alcohol and Drug Abuse and Mental Health Administration--account for the remaining 10 percent of the department's R&D.

As with defense, most R&D funded by HHS is performed externally. In 1990, nearly 60 percent of its R&D funding went to colleges and universities. Other nonprofit institutions, including hospitals, received 15 percent. Less than 5 percent went to industrial firms, either directly or through federally funded research and development centers. Roughly 20 percent was performed internally. Historically, nonprofit institutions have accounted for 70 percent of R&D funded by HHS.

In contrast to the Defense Department, HHS spends most of its R&D funds on basic and applied research. In 1990, basic research received 57 percent of the funding, applied research received 33 percent, and development received less than 10 percent. These shares also characterize HHS's spending for R&D in the 1980s, although in earlier periods the relative shares of applied and basic research were reversed from those in the 1980s.

National Aeronautics and Space Administration. Most spending for R&D by the National Aeronautics and Space Administration (NASA) supports its missions to promote space science and the exploration of space, with aeronautical R&D accounting for only 15 percent of spending in 1990. NASA's spending for R&D rose by 40 percent between 1980 and 1990, after accounting for inflation. Until the increase of the 1980s, NASA's R&D budget had been in decline since reaching its peak during the Apollo program of the 1960s. The development of large systems, such as the space shuttle and the space station, accounts for most of the fluctuation in NASA's R&D spending. When the space shuttle started operating in the early 1980s, some of NASA's spending was shifted out of R&D and into other categories of spending. The start of development spending for the space station and new spending for large space science projects have accounted for most of the increase in the late 1980s.

In 1990, industrial firms performed 50 percent of NASA's R&D. About 30 percent was performed internally, and nonprofit agencies and federally funded centers, largely universities, accounted for most of the rest. The current share of R&D funded by NASA and performed by industrial firms is higher than the 40 percent that was typical of the 1980s. The share could climb to almost two-thirds if NASA proceeds with the large missions planned for the 1990s, and if they follow the pattern of previous large development programs--such as Project Apollo in the 1960s and the shuttle in the 1970s.

In 1990, NASA spent 55 percent of its R&D budget on development. The remainder was evenly split between basic and applied research. Taking on a new large project--the space station or the Earth Observation System, for example--will drive up the development share of NASA's R&D budget.

Department of Energy. Adjusted for inflation, Department of Energy (DOE) spending for R&D has been roughly constant since 1983.[14] The current level is about 30 percent below that enjoyed in 1979, at the height of interest in energy research. The latter level represented a doubling of spending since 1973. In the 1960s and early 1970s, DOE's budget for R&D had fluctuated between one-half and two-thirds of the peak level that it reached during the energy crisis of the 1970s.

Department of Energy funding for R&D was divided among three principal programs in 1990: energy supply, 45 percent; national defense, 44 percent; and general science, 12 percent. The energy supply program performs basic and applied research on nuclear fuels and other forms of energy, including fossil fuels and solar energy. The national defense program develops and tests nuclear weapons. The general science program conducts research in high-energy physics and nuclear science. The shares that each program claims have varied in response to changing national priorities--energy supply in the 1970s, for example, and the military buildup in the 1980s.

In 1990, 54 percent of DOE's R&D funding was for development. The remainder was split between basic research (26 percent) and applied research (19 percent). For much of the 1980s, development accounted for 55 percent to 60 percent of R&D. During the energy crisis, development spending accounted for a much higher fraction of all DOE's spending for R&D, exceeding 75 percent in some years. During the 1960s and early 1970s, development spending fluctuated around 70 percent of all the department's R&D.

Two-thirds of DOE's R&D in 1990 was performed at federally funded centers. Most of this was performed at centers run by nonprofit institutions, but institutions run by industry performed 45 percent. Historically, the federally funded centers have dominated DOE's R&D, although the share performed by industry increased during the energy crisis.

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[14] The Department of Energy was created in 1976, incorporating several other agencies. In the discussion that follows, the term DOE includes the agencies that preceded it and were incorporated into it.

National Science Foundation. Adjusted for inflation, R&D spending by the National Science Foundation (NSF) grew by a third between 1980 and 1990. This growth followed a period from 1972 to 1983 when the trend in R&D funding for NSF was flat. During the 1960s, NSF funding tripled from a very low base. Spending by NSF accounted for 1.1 percent of federal R&D in 1960 and almost 3 percent in 1990. The Bush Administration has adopted the goal of its predecessor, seeking to double the NSF budget's 1987 level by 1994.

The NSF budget for R&D can be divided into four areas: research, education and human resource development, the Antarctic Program, and salaries and expenses. Research, including support for the purchase or construction of research equipment, accounts for most NSF spending. In 1990, such spending accounted for over 75 percent of appropriations. These funds are given to the NSF directorates, which specialize in engineering, information systems, geosciences, life and social sciences, and mathematical and physical sciences. About 10 percent of NSF funds go to education, including preparation of teachers at all levels of education. About 7 percent of funds go to the Antarctic Program, for which the NSF is entirely responsible. The rest of NSF funding goes for salaries and expenses.

Over 90 percent of NSF research funds are for basic research, about three-quarters of which is conducted at colleges, universities, or federally funded research centers. Most of these research projects are initiated by requests for grants from academic investigators. The extent of academic participation in basic research distinguishes the United States from Europe and Japan, where government-sponsored research institutes conduct most such research, and universities concentrate on teaching. Thus, the graduate training of scientists and engineers in the United States typically involves participation in research projects that require outside funding.

Other Agencies. The Department of Agriculture accounts for just under 2 percent of total federal R&D spending. Federal funding of experimental agricultural stations associated with land-grant colleges was first undertaken after passage of the Hatch Act in 1887 and represents the first sustained federal effort to fund research. All other agencies now individually account for less than 1 percent of total federal spending for R&D and collectively account for about 4 percent.

Tax Provisions to Encourage R&D

Tax provisions granting favorable treatment to business-financed R&D reduce federal revenues below the level that they would reach if investments for R&D were treated like other investments. These tax preferences encourage industrial R&D by lowering its after-tax cost, although their effectiveness is a matter of dispute.

One provision, granting relatively favorable tax treatment for expenses for labor and materials incurred in the conduct of R&D, has an estimated revenue cost of $1.4 billion per year. The treatment is considered preferential because the cost of labor and materials for investment in R&D can be deducted as a current expense. By contrast, the cost of investment in tangible capital can only be deducted over a period of years--a delay that significantly reduces the value of the deduction. Although this provision represents a long-standing tax preference, the original purpose appears to have been to facilitate administration, rather than to encourage R&D. For this reason, the Department of the Treasury and the Office of Management and Budget do not consider this provision to be a tax preference, although the Joint Committee on Taxation does.

A second provision provides a statutory tax credit of 20 percent for eligible R&D expenditures. The Joint Committee on Taxation estimates that this credit cost $1.2 billion in forgone revenues during 1991.[15] According to the General Accounting Office, the revenue loss resulting from the credit rose from $0.6 billion in 1981 to $1.6 billion in

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[15] The combined revenue loss from the two provisions is less than their sum because each dollar of tax credit claimed for R&D reduces the allowable deduction for qualified R&D expenses by one dollar.

1985.[16] For later years, there is no direct reporting of the revenue loss, although the Office of Management and Budget publishes an estimate. This series of estimates suggests that the revenue loss as a result of the credit stopped rising after 1985 and fluctuated around a level of slightly more than $1 billion.

Under current law the tax credit will expire in 1991, but the President's budget proposal for 1992 would make the credit a permanent part of the tax code. This provision is described further in Box 1 on page 90.

THE ECONOMIC RETURN TO FEDERAL FUNDING OF R&D

Both production-function and cost-benefit studies have been used to estimate the rate of return to federally funded R&D.[17] The production-function approach employs statistical techniques to uncover the contribution of R&D to productivity in firms or industries, using data on levels of R&D and productivity over some historical period. This approach yields overall quantitative results, but overlooks detail. By contrast, the cost-benefit approach tries to trace the path of R&D to new products or processes. This approach uncovers detail, but sometimes yields results that are limited in scope.

Trying to measure the economic return to R&D is an uncertain venture still in its infancy. Neither approach can offer more than broadly focused and tentative answers about the past--helping to determine, for example, only the general level or stability of rates of return. Both approaches are plagued by problems in measuring relevant concepts.

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[16] General Accounting Office, *The Research Tax Credit Has Stimulated Some Additional Research Spending* (September 1989), p. 14, for years before 1986. For later years, the *Special Analyses, Budget of the United States Government* provide estimates of the revenue loss from this provision.

[17] For convenience, federally funded and privately funded R&D will be referred to as federal and private R&D.

BOX 1
The Economic Effect of the Tax Credit for R&D

Current law applies a tax credit of 20 percent to eligible spending for research and development (R&D), allowing a firm to deduct 20 percent of such spending from its federal tax bill. The credit was introduced in 1981 as a temporary measure, but has been modified and extended several times. Advocates of the credit argue that it offers incentives to increase R&D uniformly among firms and industries and leaves the choice of projects in the private sector. Critics contend that the credit encourages little additional R&D, and so provides a subsidy to firms that would undertake the R&D anyway.

Before 1989, the law's provisions made the effective rate of the credit much lower than the statutory rate. The law allowed a credit for any qualified R&D expenses above a firm's R&D base--defined as the average of such expenses during the previous three years. This provision was intended to provide the credit only for qualified R&D beyond what the firm would have undertaken anyway. But the provision significantly reduced the effective rate of the credit, because a dollar spent one year reduced the credit allowed over each of the next three years by one-third of a dollar.

A change in the law in 1989 removed this perverse effect, but may have disadvantaged some firms. The law now makes the R&D base equal to a fixed percentage of a firm's average gross receipts over the previous four years. This fixed percentage is given by the ratio of a firm's qualified R&D expenses from 1984 through 1988 to its gross receipts in the same period. But this period witnessed a recession in the electronics industry, so the share of gross receipts that some firms devoted to R&D was quite high. Therefore, in more normal times, some of these firms may be unable to reach their R&D base, which would eliminate the incentive effects of the credit to those firms.

Most observers agree that the tax credit has increased private R&D by a modest but measurable amount. For instance, the General Accounting Office in 1989 estimated that the credit, as it was structured before that year, stimulated 15 cents to 36 cents in additional R&D for every dollar of tax revenue forgone.[1] A survey of other statistical studies reported that if the pre-1989 provisions had been made permanent, a 25 percent tax credit would have stimulated 36 cents to 93 cents of additional R&D for each dollar of tax revenue forgone. But evidence from surveys of firms suggested more modest effects, particularly because many firms appear to have responded to the tax incentive by relabeling various spending as R&D, rather than actually increasing their R&D.[2] This relabeling would cause a statistical study to overestimate the influence of the tax credit because the reported increase in R&D would be greater than the actual increase.

No studies of the effect of the current provisions of the tax credit on private R&D have yet appeared. Therefore, the effectiveness of the credit remains an unsettled issue.

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1. General Accounting Office, *The Research Tax Credit Has Stimulated Some Additional Research Spending* (September 1989), p. 30.

2. Joseph J. Cordes, "Tax Incentives and R&D Spending: A Review of the Evidence," *Research Policy*, vol. 18 (June 1989), pp. 119-133.

Even when these studies establish a relationship between R&D and productivity, they cannot guarantee that the relationship will persist. Certain R&D projects were undertaken because particular technical opportunities suggested they would yield benefits. But spending additional amounts will not yield the same benefits if those technical opportunities have now been exhausted. Therefore, retrospective studies cannot determine which specific R&D projects are most likely to be fruitful in the future.

A third approach, which is qualitative rather than quantitative, tries to identify attributes of successful federal R&D programs rather than estimate rates of return. Although investigators using this approach rely partly on numerical evidence, they draw conclusions largely on the basis of qualitative judgments rather than measurable characteristics. Adherents of this approach believe that quantitative analysis cannot yet make the fine distinctions necessary to guide policy. The general lessons drawn from qualitative studies, however, may sometimes be difficult to apply to specific cases.

The Production-Function Approach

Production-function studies can be applied only to part of federal R&D because a substantial portion of such R&D is undertaken within government or by nonprofit institutions to serve the missions of various government agencies. But, by the nature of the data, there are no measured productivity gains in these sectors. The national income accounts, the source of data for these sectors, measure their output only as the cost of their labor inputs. So, for example, if the government undertakes a project to photograph Jupiter, the measure of government output--that is, the cost of labor--will be the same whether the mission is successful or not. Moreover, unlike the case of physical infrastructure, there is no statistical evidence to suggest that mission-oriented research that is federally performed leads to measurable productivity gains in the private sector. Such R&D might eventually do so, but statistical methods cannot detect its influence.

As a consequence, analysts have to confine their investigations to two sectors in which available data may allow the measurement of any contribution of federal R&D to productivity. The first is R&D conducted by industry under federal contract (federal contract R&D). This type of R&D, which constitutes about half of all federal R&D, usually leads directly to products that private industry sells to the government and often leads indirectly to products that are sold to the private sector (jet engines, for example, were first developed for the military and were later adapted for commercial use). Because the output of most industries is measured independently of the cost of its inputs, it may be possible to detect the influence of federal contract R&D on productivity. In 1990, about 82 percent of federal contract R&D was for development, 16 percent was for applied research, and 2 percent was for basic research. The second type of federal R&D whose influence may be measured is agricultural R&D, which constitutes about 2 percent of federal R&D and leads to increased farm output.

The Results of Production-Function Studies. Production-function studies of the return to federal contract R&D have usually failed to find significant effects. The first study of this sort found that productivity in manufacturing industries was more strongly associated with private R&D than with federal contract R&D.[18] Later studies largely confirmed this finding. One estimated the return to private R&D in manufacturing industries to be 37 percent, but found the return to federal contract R&D to be near zero and statistically insignificant.[19] Moreover, the same study found that private R&D performed by some industries "spilled over" by also contributing to productivity in industries they supplied, whereas federal contract R&D did not.[20] (A cost-benefit study confirmed this latter finding by estimating that the total return from private R&D to society as a whole is more than twice the return to the private investor.)[21] Other studies have reached similar conclusions.[22]

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[18] William N. Leonard, "Research and Development in Industrial Growth," *Journal of Political Economy*, vol. 79 (March/April 1971), pp. 232-256.

[19] The rate of return considered here is real, rather than nominal, but differs from a real net yield because it includes the rate of depreciation of the accumulated store of R&D. This depreciation rate on industrial R&D cannot be directly observed, but may be on the order of 10 percent annually.

[20] Nestor E. Terleckyj, "Direct and Indirect Effects of Industrial Research and Development on the Productivity Growth of Industries," in John W. Kendrick and Beatrice N. Vaccara, eds., *New Developments in Productivity Measurement and Analysis* (Chicago: University of Chicago Press, 1980), pp. 359-377.

One study, however, offered tentative evidence that basic research performed under federal contract contributes to productivity even though similarly funded applied R&D does not.[23] The study essentially provides qualitative rather than quantitative evidence. It considered a small sample of manufacturing firms and found either low or insignificant rates of return to all forms of R&D. It did find, however, a significant statistical relationship between productivity and federal basic research, which no other studies have distinguished from other federal R&D.

Production-function studies of federal R&D in agriculture stand in sharp contrast to those of federal R&D in general. A survey of 11 studies conducted between 1964 and 1981 reported (with one exception) significant rates of return ranging from 21 percent to 110 percent, with most lying between 33 percent and 66 percent.[24] The studies are remarkable for consistently estimating high rates of return, given differing data sources and continual refinements of estimating techniques.

The general absence of statistical association between most federal contract R&D and productivity seems surprising, because a strong association exists between private R&D and productivity. Numerous statistical studies done since the mid-1960s have estimated rates of return to private R&D typically ranging from 20 percent to 50 percent.[25] The most recent studies estimate that the rate of return has been toward the lower end of the range, but find little evidence that it has been declining.[26] In particular, changes in R&D spending do not seem to have been responsible for much of the slowdown in economywide productivity experienced in the 1970s and 1980s (see Box 2).

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[21] Edwin Mansfield and others, "Social and Private Rates of Return from Industrial Innovations," *Quarterly Journal of Economics*, vol. 91 (May 1977), pp. 221-240.

[22] David M. Levy and Nestor E. Terleckyj, "Effects of Government R&D on Private R&D Investment and Productivity: A Macroeconomic Analysis," *The Bell Journal of Economics* (Autumn 1983), pp. 551-561. See also Zvi Griliches and Frank Lichtenberg, "R&D and Productivity at the Industry Level: Is There Still a Relationship?" in Zvi Griliches, ed., *R&D, Patents, and Productivity* (Chicago: University of Chicago Press, 1984); Zvi Griliches, "Productivity, R&D, and Basic Research at the Firm Level in the 1970s," *American Economic Review*, vol. 76 (March 1986), pp. 141-154; Zvi Griliches, "Returns to Research and Development Expenditures in the Private sector," in John W. Kendrick and Beatrice N. Vaccara, eds., *New Developments in Productivity Measurement and Analysis* (Chicago: University of Chicago Press, 1980), pp. 419-456.

[23] See Albert N. Link, "Basic Research and Productivity Increase in Manufacturing: Additional Evidence," *American Economic Review*, vol. 71 (December 1981), pp. 1111-1112.

[24] Robert D. Weaver, "Federal Research and Development and U.S. Agriculture: An Assessment of Role and Productivity Effects" (paper presented at the National Academy of Sciences' Workshop on "The Federal Role in Research and Development," November 21-22, 1985).

Why Production-Function Studies May Not Find Returns to Most Federal Contract R&D. Two explanations have been proposed for the apparent lack of contribution to productivity by most federal contract R&D. The first suggests that problems of measurement mask its contribution, the second that its interaction with private R&D does. Neither explanation appears to tell the whole story.

Problems of Measurement. The measured influence of federal R&D on productivity may be low relative to that of private R&D if the federal and private sectors fund different types of R&D. One type of R&D leads to new and better products, but measuring the enhanced output embodied in new products is difficult. To the extent that an increase in output owing to R&D is not fully measured, the R&D will notappear to have improved productivity. By contrast, it is easier to measure productivity arising from a second type of R&D that leads to cheaper ways to make existing products. In this case, it will be clear that a given unit of product is being produced with fewer inputs (provided that the industry's output is measured independently of its inputs). Private R&D may appear to yield higher returns than federal R&D if relatively more private R&D is aimed at developing cheaper processes, rather than new products. Many observers believe that this is so, but no reliable data exist on this question.

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[25] For surveys, see Congressional Budget Office, *Federal Support for R&D and Innovation* (April 1984), pp. 27-31; and Office of Technology Assessment, *Research Funding as an Investment: Can We Measure the Return?* (April 1986), pp. 13-16.

[26] Zvi Griliches, "Productivity Puzzles and R&D: Another Nonexplanation," *Journal of Economic Perspectives*, vol. 2 (Fall 1988), p. 15.

BOX 2
The Role of R&D in the Productivity Slowdown

High estimated rates of return to private research and development (R&D) suggest two questions about the relationship of R&D to the slowdown in productivity growth that has occurred in the United States in recent decades. First, did a slowdown in R&D expenditures help cause the productivity slowdown? Second, has the rate of return to R&D fallen, so that a given rate of R&D expenditures translates into a slower rate of productivity growth? Evidence is mixed, but largely suggests that the answer to both questions is "no."

Results of studies vary, but most suggest that slower growth of R&D expenditures could account for no more than about 15 percent of the recent slowdown in the growth of total factor productivity--the growth of output that cannot be explained by the growth of capital and labor inputs. Even if high rates of return to R&D are assumed, the changes in expenditures for R&D were too small to account for the large changes in productivity. Less direct evidence also suggests that R&D is not the principal culprit in the productivity slowdown. First, productivity growth fell even more in other industrial countries, where expenditures for R&D did not slow as much. Second, most of the slowdown in R&D in the United States occurred in federal R&D, which shows far less influence on measured productivity than private R&D.

In general, studies provide no compelling evidence of a permanent decline in the return to R&D, which also casts doubt on the idea the R&D helped cause the productivity slowdown. Studies that do suggest a decline in the rate of return seem to rest on fragile foundations. Their results depend critically on the level of aggregation, the type of R&D they considered, or the specific way in which relationships are expressed in the estimation procedure. Some evidence suggests that any decline may have been confined largely to traditional manufacturing industries, with high-technology industries showing no recent decline. But traditional industries are the ones that have been most plagued by excess capacity, which is associated with sluggish growth in productivity.

In any case, the data contain enough anomalies to suggest that the slowing in productivity may be exaggerated. For example, reported indices of productivity in construction, wholesale and retail trade, and service industries were lower in 1985 than in 1973--clearly, an implausible outcome. But measuring the real output of these industries is problematic. By contrast, productivity growth in manufacturing, whose output is least difficult to measure, exhibits no strong trends or discontinuities during the postwar period.[1]

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1. See Zvi Griliches, "Productivity Puzzles and R&D: Another Nonexplanation," *Journal of Economic Perspectives*, vol. 2 (Fall 1988), pp. 9-21.

Interactions with Private R&D. Interactions between federal and private R&D may also confound attempts to measure the return to federal R&D. Such interactions could occur in two ways. On the one hand, federal R&D could crowd out private R&D by driving up costs of labor and material inputs that both use, such as engineers and scientific instruments. The crowding out would indirectly reduce the contribution to productivity of increased federal R&D by reducing private R&D at the same time. On the other hand, federal R&D could stimulate additional private R&D by making it more productive. If federal R&D stimulates more private R&D, then federal R&D would indirectly raise productivity through its influence on private R&D. In this event, statistical studies will mistakenly assign the benefits of federal R&D to private R&D. A voluminous literature has found somewhat mixed results on the interaction between federal and private R&D, but suggests that its overall importance is probably small.[27]

Conclusion. The failure of production-function studies to find consistent positive effects of most federal contract R&D puzzles many observers because of their strong a priori supposition that federal R&D has helped private R&D to be productive. Virtually all observers believe, for instance, that military R&D and procurement have significantly influenced the development of commercial technology in such areas as aviation, electronics, computers, and nuclear power. Still, production-function studies largely fail to detect any significant influence in the data. This failure does not clearly result from problems with measurement or statistical methods. Statistical tests can in fact detect effects on productivity flowing from private R&D both in the sectors that undertook the R&D and produced the product and in downstream sectors they supply.

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[27] These results are reviewed in Frank R. Lichtenberg, "Assessing the Impact of Federal Research and Development on Private Research and Development" (paper presented at the National Academy of Sciences' Workshop on "The Federal Role in Research and Development," November 21-22, 1985); and David Levy and Nestor Terleckyj, "Effects of Government R&D on Private R&D Investment and Productivity." See also Zvi Griliches and Frank Lichtenberg, "R&D and Productivity at the Industry Level."

The Cost-Benefit Approach

Cost-benefit analysis has been used to determine the rate of return to research by identifying the value of benefits arising from particular innovations and the costs that were required to effect them. But the narrow focus of the studies sometimes makes overall results hard to assess. Analyses also tend to focus on successes, making overall evaluations more difficult.

Counting the benefits and costs of R&D may seem conceptually straightforward, but many practical problems arise. Unlike production-function studies, which use statistical methods to test for and measure the results of R&D, cost-benefit studies require the analyst to assume that he or she can identify the returns beforehand. Analysts find it difficult to account for spillovers (positive or negative) and to draw the line at where the benefits and costs start and end. (When do the benefits of medical research end? Should the cost of basic research in genetics be included in assessing the development of hybrid corn?) As a result, analyses tend to include only the most direct benefits and costs.

Cost-Benefit Studies That Yield Positive Results. Cost-benefit studies in two areas--health and academic research in science and engineering--suggest significant returns. The evidence is limited, however, in that only one comprehensive study in each area has appeared--and the study on health appeared over 10 years ago. Further, although most such research is federally funded, no study has distinguished the returns on federally funded R&D from the returns on nonfederally funded R&D.

Cost-benefit analyses of R&D in medicine have concluded that such projects yield significant returns. One study found that R&D devoted to polio earned a rate of return that, except under the most extreme assumptions, was at least 5 percent and probably 11 percent to 12 percent.[28] These estimates are conservative in that they measure benefits only in market terms (increase in output attributable to reduced mortality or morbidity) and do not include benefits to other countries.

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[28] Burton A. Weisbrod, "Costs and Benefits of Medical Research," *Journal of Political Economy*, vol. 79 (May/June 1971), pp. 527-544.

Another, more comprehensive, study used statistical analysis to determine the extent to which biomedical research (about two-thirds of which is federally funded) reduced the mortality rate between 1930 and 1975. Using these results, the author estimated the value of output gained from the reduced death rate and calculated a rate of return on biomedical research of 46 percent.[29] This return would go largely undetected in ordinary measures of productivity (output per unit of combined capital and labor input) because the reduced rates of death and illness would increase labor as well as output, leaving productivity largely unchanged.

Economic returns, however, are usually not the sole, or perhaps even the leading, criterion in evaluating the mission of expanding frontiers in health. For example, economic measures cannot resolve the ethical dilemmas facing policymakers in deciding to allocate funds to try to reduce heart attacks among the middle-aged, cancer among the elderly, or sudden infant death syndrome among the young.

One study has measured the rate of return to academic research in science and engineering as 28 percent.[30] Most such research is federally funded basic or applied research, which provides returns that are difficult for private firms to appropriate. As the author emphasizes, the study used samples that were considered typical, but which were not random, so sampling error might critically affect the results. In addition, the calculations depend on many rough approximations, although the author tried to use conservative assumptions. The study is noteworthy because it provisionally quantifies the intuition of many observers: that academic research provides a wellspring of technical progress.

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[29] Selma J. Mushkin, *Biomedical Research: Costs and Benefits* (Cambridge: Ballinger Publishing Co., 1979).

[30] See Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy*, vol. 20 (February 1991), pp. 1-12.

Cost-Benefit Studies That Yield Mixed Results. Cost-benefit studies in two areas--aeronautics and independent defense-related R&D--yield inconclusive results. In part, this difficulty stems from ambiguity in defining costs and benefits.

One study of R&D in aeronautics illustrates how sensitive the results can be to the question of which costs and benefits should be included.[31] Using data for commercial aviation for the period 1966 to 1983, the author estimated the rate of return to private and civilian-related federal R&D in aeronautics to be 24 percent. But, the author maintains, the increase in productivity implied by this rate of return is not entirely accounted for by R&D. Instead, he argues, regulation by the Civil Aeronautics Board inadvertently contributed by hastening the introduction of airplanes embodying the newly developed technologies. Regulation led to artificially high demand by the airlines for bigger and faster planes by forcing the airlines to compete on the basis of amenities and speed, rather than price. At the same time, this regulation held airfares at artificially high levels. Most economists agree that regulations that have this effect impose costs on society because they make the use of resources less efficient. If these costs are included in the benefit-cost calculation, the calculated rate of return falls to minus 3.8 percent. Other considerations also compound the ambiguity in measuring the rate of return to R&D in this area.

Three studies differ widely on the effectiveness of independent R&D sponsored by the Department of Defense to increase private R&D for defense applications. One study suggested that each dollar of independent R&D induced an additional $2.20 of private R&D.[32] Two other studies, however, found that the true addition to private R&D is negligible, and that probably about 50 percent--and perhaps as much

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31. David C. Mowery, "Federal Funding of R&D in Transportation: The Case of Aviation" (paper presented at the National Academy of Sciences' Workshop on "The Federal Role in Research and Development," November 21-22, 1985).

32. Arthur J. Alexander, Paul Hill, and Susan Bodilly, *The Defense Department's Support of Industry's Independent Research and Development: Analysis and Evolution*, RAND Corporation Report No. R-3649-ACQ (Santa Monica, Calif.: RAND Corporation, April 1989).

as 80 percent--of the cost of the program is pure subsidy.[33] The evidence is also mixed on the cost effectiveness of independent R&D in serving the defense mission.

Qualitative Studies

A final source of evidence in evaluating federal R&D programs lies in a group of studies that attempt to identify attributes of economically valuable federal research rather than to estimate rates of return.[34] Some general lessons can be drawn from these studies, but they may be difficult to apply to specific cases. First, success seems more likely when R&D programs advance well-defined public purposes, especially when the government is a major purchaser of the eventual output. For example, military demand for high-speed computers and electronic components undoubtedly hastened their commercial development. Second, experience in products and fields like semiconductors, pharmaceuticals, agriculture, computers, and aircraft suggests that government involvement in basic research and generic applied research (the benefits of which would likely accrue to one or more industries rather than to specific firms within an industry) may facilitate diffusion of the results.[35] Third, private investors are likely to be more successful than the government in "picking winners"--that is, identifying the most economically fruitful technologies to develop commercially.[36] Experiences in housing and energy have illustrated this lesson.

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[33] Frank R. Lichtenberg, "Government Subsidies to Private Military R&D Investment: DoD's IR&D Policy," Columbia University Graduate School of Business (June 1988); and John R. Brock, Jr., "Federal Subsidies for Research and Development: The Department of Defense Independent Research and Development Program" (Ph.D. Dissertation, Columbia University, August 1988).

[34] This account draws in part from Richard R. Nelson, "Government Stimulus of Technological Progress: Lessons from American History," in Richard R. Nelson, ed., *Government and Technical Progress: A Cross-Industry Analysis* (New York: Pergamon Press, 1982), pp. 451-482.

[35] In line with this argument, a recent study recommended shifting federal R&D away from large programs to enhance national prestige (the space station and Superconducting Super Collider are commonly cited examples) and toward programs supporting applied research in order to help the results of the research find useful commercial applications. See Council on Competitiveness, *Gaining New Ground* (Washington, D.C.: Council on Competitiveness, 1991).

[36] For a further discussion of these issues, see Congressional Budget Office, *Using Federal R&D to Promote Commercial Innovation* (April 1988).

In practice, however, it is difficult to distinguish between supporting generic research and trying to pick winners. For example, does funding applied research for high-definition television qualify as supporting generic research or as picking a winning technology? Consequently, applying the second and third lessons becomes ambiguous.

CONCLUSION

How does the accumulated evidence on the economic rate of return to R&D offer guidance in evaluating federal spending for R&D? Estimates of the economic rate of return to basic and academic research offer general support for such spending--for example, for the National Science Foundation. All federal spending for such research accounts for about a quarter of federally funded R&D. In some areas of applied R&D, such as health or agriculture, economic measures also suggest generally high rates of return. Economic analysis, however, cannot determine which specific projects or areas are likely to be most fruitful. Technological expertise is needed to shed light on such issues.

More generally, however, the measured economic rate of return does not in itself offer a strong justification for most spending. Instead, spending for R&D that is primarily intended to support the missions of particular federal agencies is best evaluated on the basis of its contribution to the mission (and the perceived merit of the mission itself). Given the difficulty of measuring economic returns to most federally funded R&D, claims of substantial economic benefits beyond contributions to agency missions should be viewed skeptically and accepted only after specific cases and technologies are evaluated.